JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 1–11

ISSN: 1697-4840, www.jmr.unican.es

Australia Nuclear-Powered Submarines, Archipelagic Waters, and the New Capital City of Indonesia

P. Rovan[1,*], I. Alverdian[2]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 4 Jun 2023;
accepted 06 Jul 2023.

Keywords:
Innocent Passage, AUKUS, Archipelagic Waters, Submarines, Confidence-Building Measures.

ABSTRACT

In this article, the writer tries to provide insight and an Indonesian perspective on the potential impact of the nuclear-powered submarine acquisition program as part of the AUKUS Agreement. In particular, its defense and security implications on the archipelagic water's status of Indonesia's seas and 'Nusantara' as Indonesia's new capital city. The writers argue that current Indonesian regulations and interpretations of its archipelagic waters and nuclear-powered submarines present a potentially heightened threat perception on the part of Indonesia concerning the potential movement of Australia's future nuclear-powered submarines on the seas of the Indonesian archipelago and around Indonesia's new capital city of 'Nusantara'. Thus, it recommends enhanced confidence-building measures among senior officials of both countries to avoid misunderstanding between both countries. Specifically, as Australia's nuclear-powered submarines program will become fully operational by early and mid-2030's.

1. Introduction.

As a nation with thousands of islands, Indonesia has always had concerns over the waters that separate those islands. The waters that surround the islands are seen as an obstacle. Historically, Indonesia has preferred to embrace more *mare clausum* than *mare liberum* to reduce its water barrier. In the 1950s and 1960s, Indonesia proclaimed surrounding waters as internal waters[3]. A claim that had received numerous challenges and criticisms from the international community[4]. At the beginning of UNCLOS III negotiations, Indonesia brought the concept of an archipelagic state, with all the waters surrounding it as internal waters[5].

However, this effort was to no avail[6]. The package deal of UNCLOS 1982 validates the archipelagic concept with a much lower status of the surrounding waters. The convention accepts the status of those waters as archipelagic waters, in many ways similar to the territorial sea[7]. Even worse, Indonesia still has to provide its waterways, which are generally used for international navigation, to international shipping in a so-called "archipelagic sea lane passage."[8]

There are many unresolved problems regarding archipelagic sea lane passage. On the one hand, maritime powers, including Australia, always want to have a laxer regime of passage,

[1]Ph.D. student at the Australian National Centre for Ocean Resources and Security (ANCORS), University of Wollongong (UOW), NSW, Australia.

[2]Lecturer at the International Relations Program at President University, Indonesia.

[*]Corresponding author: P. Rovan. E-mail Address: indraalverdian@president.ac.id.

[3] By enacting UU no 4 PRP 1960 tentang perairan (Law no. 4 on Indonesian waters 1960). In 1957 there was also well known Djuanda declaration which mentioned that waters surrounding Indonesian archipelago as Indonesian waters. During UNCLOS II negotiation, Indonesia and the Philippines tried to bring the concept of archipelago to the forum, but it failed.

[4] France, the U.S., the U.K., Australia, New Zealand, Japan, and the Netherland protested toward Indonesia. See: Ku, Charlotte. "The archipelagic states concept and regional stability in Southeast Asia." Case W. Res. J. Int'l L. 23 (1991): 463, page 470.

[5] Draper, Jack A. "The Indonesian archipelagic state doctrine and Law of the Sea: Territorial grab or justifiable necessity." In Int'l L., vol. 11, p. 143. 1977.

[6] The package deal of UNCLOS 1982 recognizes of interconnecting waters as archipelagic waters, not internal waters. UNCLOS 1982 is considered a huge package deal for many interests of many states.

[7] In many ways, the status of archipelagic waters is similar to territorial sea. See part IV of UNCLOS 1982.

[8] Article 53(4)(12) of UNCLOS 1982.

while Indonesia always wants to have a more restricted regime of passage. This was especially true when Indonesia submitted its archipelagic sea lanes proposal to the International Maritime Organization (I.M.O.) in 1996. Maritime powers wanted more sea lanes, while Indonesia tried to limit the number of sea lanes to just three. This ultimately resulted in the rejection of maritime powers' acceptance of the submission, and I.M.O. regards the submission as a "partial submission." While Indonesia has not made a complete submission, maritime powers will treat all the waters customarily used for navigation as archipelagic sea lanes, based on Article 53(12) of UNCLOS 1982[9]. This made Indonesia worried. Ultimately, Indonesia made some rules to eliminate the threat of passing through the waters separating its islands. These regulations, including those which govern foreign nuclear-powered vessels, Australia's plan to acquire a nuclear-powered submarine will impact relations between Indonesia and Australia. This is exacerbated by the Indonesian government's decision to move its capital city to the coast of a deep and wide strait, which will become a playground for Australia's nuclear-powered submarine in the future.

2. AUKUS, Nuclear Powered Submarines, and Indonesia's Response.

Australia has a plan to build eight nuclear-powered submarines[10]. This planning is part of a deal from the framework of Australia-the U.K.-the U.S. new alliance, AUKUS[11]. This new agreement is specifically made to curb China's increasing power in the Indo-Pacific region. However, there are some controversies behind this plan. Because of this plan, Australia had to cancel its project with France, which made France furious[12]. The nuclear-powered submarine acquisition program also invites some concern within Australia, particularly regarding environmental problems[13]. All this time, Australia has always been a leader regarding nuclear issues. Even when France conducted atomic testing in the Pacific, Australia, and New Zealand applied to the I.C.J., which is well known as the nuclear test case[14]. Even though the use of atomic energy for submarine propulsion is different from acquiring nuclear weapons, the devil is in the detail, and the point has not come up yet. By using nuclear power for its submarines, legally speaking, Australia is not in contravention of the Nuclear Non-Proliferation Treaty (N.P.T.)[15] . However, it will undermine the effort to curb using atomic energy for non-peaceful purposes. Making nuclear weapons from nuclear energy specifically used for submarine propulsion is also possible[16]. The nuclear energy used for eight submarines can be used to make around 160 nuclear warheads[17]. Not to mention, this could become a precedent for other states to follow suit.

Indonesia has expressed its deep concern and caution about this plan[18]. All of that nervousness is rational, considering that a submarine is a strategic weapon that can become an immediate threat to other states. At the heart of Indonesia's concern is the potential of these nuclear-powered submarines as an integral part of AUKUS to impact the centrality of ASEAN ways of managing strategic stability in maritime Southeast Asia, particularly ASEAN Outlook on the Indo-Pacific (AOIP). As a senior Indonesian diplomat rightly points out, 'it had portent to agitate the strategic landscape of ASEAN'[19]. In particular, Jakarta is uneasy about how mini-lateral groupings such as AUKUS could impact ASEAN centrality. This position on AUKUS is a reflection of Indonesia's strategic preference for the management of the strategic challenges of the Indo-Pacific region. Specifically, the reality is that 'beyond the AIOP, The Indonesian Ministry of Foreign Affairs (MOFA) does not seem eager to explore non-ASEAN options to engage the Indo-Pacific.' Consequently, the fact that the developments of this AUKUS nuclear-powered submarines is viewed as representing a new U.S.-led regional Indo-Pacific maritime defense architecture lies at the center of

[9] Article 53(12) UNCLOS 1982 states that "If an archipelagic State does not designate sea lanes or air routes, the right of archipelagic sea lanes passage may be exercised through the routes normally used for international navigation."

[10] Buckley, Chris. "Nuclear-Powered Submarines for Australia? Maybe Not so Fast." The New York Times. The New York Times, October 29, 2021. https://www.nytimes.com/2021/10/29/world/australia/nuclear-powered-submarines.html.

[11] Some of those deals are acquisition of Tomahawk missile for Hobart class, nuclear-powered submarine, precision strike-missile for army, and for air force. See: Davis, Malcolm, AuthorMalcolm Davis is a senior analyst at ASPI. He is on Twitter at @Dr_M_Davis. Image: US Department of Defense., Author, and Malcolm Davis is a senior analyst at ASPI. He is on Twitter at @Dr_M_Davis. Image: US Department of Defense. "Aukus: Looking beyond the Submarines." The Strategist, November 4, 2021. https://www.aspistrategist.org.au/aukus-looking-beyond-the-submarines/.

[12] "'We Felt Fooled': France Still Furious after Australia Scraps $90bn Submarine Deal." The Guardian. Guardian News and Media, September 20, 2021. https://www.theguardian.com/world/2021/sep/20/we-felt-fooled-france-still-furious-after-australia-scraps-90bn-submarine-deal.

[13] Keane, Daniel. "Nuclear Subs Have 'Long History of Accidents', Environmentalist Warns." ABC News. ABC News, September 17, 2021. https://www.abc.net.au/news/2021-09-17/nuclear-submarines-prompt-environmental-and-conflict-concern/100470362.

[14] See: "Latest Developments: Nuclear Tests (Australia v. France): International Court of Justice." Latest developments — Nuclear Tests (Australia v. France) — International Court of Justice. Accessed April 23, 2022. https://www.icj-cij.org/en/case/58.

[15] For analysis regarding Australia's nuclear-powered submarine deal and article 14 of Non-Proliferation Treaty, See: "Arms Control Today." The Australia-UK-U.S. Submarine Deal: Submarines and Safeguards — Arms Control Association. Accessed April 23, 2022. https://www.armscontrol.org/act/2021-12/features/australia-uk-us-submarine-deal-submarines-safeguards.

[16] This is especially true in the case when the new submarine will use Highly Enriched Uranium (HEU), instead of Low Enriched Uranium (LEU). See: Bergmann, Kym. "Nuclear submarines: Decision of enormous consequences taken with little analysis." Asia-Pacific Defence Reporter (2002) 47, no. 7 (2021): 12-14.

[17] An analysis by Dr. Alan Cooperman. See: Lowy Institute, AUKUS and Nuclear Non-Proliferation Seminar. YouTube. YouTube, 2022. https://www.youtube.com/watch?v=AELYOw8pa_E.

[18] Sambhi, Natalie, AuthorNatalie Sambhi is executive director of Verve Research and a non-resident fellow with the Brookings Institution's foreign policy program. Image: US Navy/Flickr., Author, and Natalie Sambhi is executive director of Verve Research and a non-resident fellow with the Brookings Institution's foreign policy program. Image: US Navy/Flickr. "Australia's Nuclear Submarines and AUKUS: The View from Jakarta." The Strategist, September 20, 2021. https://www.aspistrategist.org.au/australias-nuclear-submarines-and-aukus-the-view-from-jakarta/.

[19] Djalal, Dino P. "ASEAN Responses to AUKUS Security Dynamic." Asian Review : Diplomatic Caution, East Asia Forum Quarterly, October – December 2021, pp. 16-18.

Indonesia's concern.

3. Potential Implications of Australia's Nuclear-Powered Submarines and AUKUS on Indonesia.

A submarine is a stealth weapon. A submarine is like any other warship but in a much more vulnerable state when submerged. Once the enemy has discovered its location, it will become susceptible to attack by either a surface ship or an aircraft. It will only surface if it wants to talk to friends or go snorkeling. A submarine's battery is recharged through snorkeling. This, however, applies only to conventional submarines. Snorkeling is unnecessary in the case of a nuclear-powered submarine. A nuclear-powered submarine can dive indefinitely without coming to rest. It is simply a matter of logistics for the crews, such as the food that must be victualled. A nuclear-powered submarine has a much greater range and is much faster. Although nuclear-powered submarines are noisier than conventional submarines in some cases, their overall performance is far superior to that of their counterparts. Put another way, a nuclear-powered submarine is less vulnerable because it does not need to surface to recharge its battery.

In contrast, to surface warships, which can easily be detected using modern radar or other surveillance systems, searching for submarines while they dive under the sea is challenging. For example, it takes several days to locate the wreckage of an airliner that crashed into shallow water using the most advanced technology, let alone search for a stealthy, moving, and silent submarine in deep water. A submarine, in the past, was a type of warship that could only be used for naval warfare, targeting surface ships such as warships or merchant ships. Submarines were a nightmare for surface ships during World War I and II. A submarine today has many functions and armaments. A modern nuclear-powered submarine can even carry a nuclear warhead to destroy an entire town. Another process of a nuclear-powered submarine is to project power onto the land. A nuclear-powered submarine typically has a submarine-to-land missile capable of being launched from the depths of the ocean to land.

The most important strength of a nuclear-powered submarine compared to a conventional sub is its endurance[20]. It can go unlimited in terms of fuel[21]. With an exceptionally long stationing time, the future Australian nuclear-powered submarine could travel far north, close to Chinese waters, undetected[22]. A nuclear-powered submarine does not need to snorkel. With these two advantages, Australia's future nuclear-powered submarine will also be capable of sailing through the archipelago without snorkeling and refueling. The one thing that will make Australia's nuclear-powered submarine has a high deterrence effect is its armament, which is much better than the Collins class. She will likely carry a Tomahawk missile for a land target[23]. Even though it is not a nuclear warhead, it will still have a considerable deterrence effect[24]. With its hundred-mile range, many cities in Indonesia will certainly be within its content, including the new capital city, located on the coast of Makassar Strait. As one of the closest neighbors, Indonesia should be wary of the AUKUS agreement. Moreover, Indonesia is a vast archipelagic state with three archipelagic sea lanes and many straits and waterways that are deep and wide enough for submarine areas of operation. Even though, from a geopolitical perspective, Australia's projection is undoubtedly China[25], it should be inconvenient to see your neighbor's nuclear-powered submarine swim in front of your nose silently, significantly if it can threaten you with its subsurface-to-land cruise missiles[26].

Another dimension to these nuclear-powered submarines is how they may potentially fit in overall Indonesia's defense and security establishment consideration on the broader AUKUS agreement. First, it's not only the endurance capabilities of these nuclear-powered submarines but how Australia can ensure that it has developed an effective and independent governance regime to manage nuclear power. As the late retired admiral James Goldrick points out, 'it is not the operations of the submarines themselves that will be subject to any real loss of national autonomy in a mature system but the working of the regime's governance for nuclear power'[27]. Separately, the development of the Virginia Class SSN is also aligned with another pillar of AUKUS: the development of joint advanced undersea warfare capabilities. A noted expert on Australian defense policy has stressed that 'although the focus has been on the pathways to acquiring SSNs, this capability should be seen as a component of a system of the system in the 21st century undersea operations, whereas crewed submarines such as Virginia or SSN AUKUS boats will operate alongside smaller unmanned underwater vehicles deployed from submarines'[28]. The previous argument relates to the second, which is changes in Indonesia's maritime threat perception due to the nuclear-powered submarines. Historically, Indonesian defense establishment threat perception has been on 'Australia's sovereign

[20] Lambert, R. J. W. "Environmental Problems in Nuclear Submarines: The Nuclear Submarine Environment." (1972): 795-796.

[21] The U.S. nuclear-powered submarine for example, only need more than 30 years of replacement of its uranium. Read: Jeon, Byeongdoo, and Mojdeh Khorsand. "Energy Management System in Naval Submarines." In 2020 IEEE Transportation Electrification Conference & Expo (ITEC), pp. 802-808. IEEE, 2020.

[22] Person. "Aukus and Australia's Nuclear Submarines." The Interpreter. The Interpreter, September 27, 2021. https://www.lowyinstitute.org/the-interpreter/debate/aukus-and-australia-s-nuclear-submarines.

[23] Just like the U.K's Astute class and the U.S.'s Virginia class, Australia's future nuclear-powered submarines will also carry tomahawk cruise missile for surface and land target. See: Patrick, Aaron. "Australia's Eight Nuclear Subs Will Be Designed to Outclass China." Australian Financial Review, September 16, 2021. https://www.afr.com/policy/foreign-affairs/australia-s-eight-nuclear-subs-will-be-designed-to-outclass-china-20210916-p58s1n.

[24] Read: Mustin, Henry C. "The Sea-Launched Cruise Missile: More Than a Bargaining Chip." International Security 13, no. 3 (1988): 184-190.

[25] https://www.globaltimes.cn/page/202203/1254240.shtml

[26] The new submarines will have subsurface to land missiles which can become strategic deterrence. See: Staff, Naval News. "Leak Reveals First Details of Australia's New Aukus Submarine." Naval News, April 2, 2022. https://www.navalnews.com/naval-news/2022/04/leak-reveals-first-details-of-australias-new-aukus-submarine/.

[27] Goldrick, James, "Understanding Australia's Submarine Commitment", The Strategist, Australian Strategic Policy Institute, 9 February 2023.

[28] Davis, Malcolm, "Australian SSNs will open up opportunities for advanced undersea operations", The Strategist, Australian Strategic Policy Institute, 15 March 2023.

submarine capability.' On the other hand, it must now develop a defensive response capacity towards an 'alliance submarines capabilities' with the possible integration of undersea warfare capabilities among AUKUS members.

4. Indonesian Regulations on Archipelagic Waters and Nuclear - Powered Submarine.

Australia's nuclear-powered submarine will be highly likely to use archipelagic waters to navigate north to Australia's target projection, China[29]. Some elements of international law should be noted by navigating within the archipelagic waters. According to UNCLOS 1982, foreign nuclear-powered submarines can use innocent passage and archipelagic sea lane passage. Based on article 53(1) of UNCLOS 1982, Indonesia, as an archipelagic state, may designate archipelagic sea lanes within its archipelagic waters. This is compensation for accepting the archipelagic state concept during the 1982 UNCLOS negotiations, which converted high seas between islands into archipelagic waters[30]. So far, Indonesia has designated three archipelagic sea lanes to accommodate shipping[31]. UNCLOS 1982 regulates nuclear-powered vessels in articles 22 and 23 within Section 3 of innocent passage in the territorial sea. Article 22 states that nuclear-powered ships may be required to navigate within specific traffic separation schemes (T.S.S.). In article 23, it is stated that "nuclear-powered vessels shall carry documents and observe special precautionary measures established for such ships by international agreements." There is no special treatment for warships in this case. As long as a particular ship is a nuclear-powered vessel conducting innocent passage, she shall obey these rules. In article 30 of the convention, the coastal state can ask the incompliance warship to leave the territorial sea[32].

However, it is still unclear how the coastal state can technically check the documents of foreign nuclear-powered warships. This is especially true since states that own nuclear-powered warships are maritime powers. Regarding innocent passage within archipelagic waters, there are no specific rules. The same regulations for innocent passage within territorial seas also apply to innocent passage within archipelagic waters. This includes rules that govern nuclear-powered vessels. This is based on Article 52 of UNCLOS 1982. UNCLOS 1982 has no regulations regarding nuclear-powered vessels when conducting transit passage and archipelagic sea lane passage. This means nuclear-powered vessels have no restrictions for conducting transit passages and passages through archipelagic sea lanes. There is also no prior authorization or notification from nuclear-powered warship operator states to the coastal states needed before or during archipelagic sea lane passage.

The Indonesian government regulates innocent passage in government regulation number 36 (2002) regarding the rights and obligations of foreign ships when conducting innocent passage within Indonesian waters. Based on article 11 of the Indonesian government regulation regarding innocent passage number 36 (2002), nuclear-powered vessels shall only use four routes to conduct innocent passage[33]. It turns out that those four routes are identical to Indonesian archipelagic sea lanes based on government regulation number 37 (2002) regarding the rights and obligations of foreign ships and aircraft when conducting archipelagic sea lane passage within designated archipelagic sea lanes (see Figure 4). Those designated archipelagic sea lanes are the same as those in Indonesia's 1996 "partial submission" to I.M.O. This regulation does not differentiate between merchant vessels, government ships, or warships. Another regulation regarding foreign nuclear-powered vessels during innocent passage is Article 16 Law Number 6 (1996). It states that:

"Foreign nuclear-powered ships.... shall carry documents and observe special precautionary measures established for such ships by international agreements."[34]

No other rule governs foreign nuclear-powered vessels during the innocent passage.

Meanwhile, the Indonesian government regulates archipelagic sea lane passage in Government Regulation 37 (2002) regarding the rights and obligations of foreign ships and aircraft when conducting archipelagic sea lane passage within designated archipelagic sea lanes. Based on article 9 states that:

"Foreign nuclear-powered ships when.... conducting archipelagic sea lane passage (within designated archipelagic sea lanes) shall carry documents and observe special precautionary measures established for such ships by international agreements."[35]

[29] To go north to South China Sea or East China Sea, the best routes will be via Indonesia's archipelagic waters.

[30] Ku, Charlotte. "The archipelagic states concept and regional stability in Southeast Asia." Case W. Res. J. Int'l L. 23 (1991): 463.

[31] In 1996, Indonesia submitted "partial designation" of archipelagic sea lanes to International Maritime Organization (IMO). See: Warner, Robin. "Implementing the archipelagic regime in the International Maritime Organization." In Navigational Rights and Freedoms and the New Law of the Sea, pp. 170-187. Brill Nijhoff, 2000.

[32] Article 30 UNCLOS 1982.

[33] Those routes are as follows: a. route 1: Natuna Sea, Karimata Strait, Java Sea, and Sunda Strait. b. route 2: Makassar strait, Flores Sea, and Lombok Strait. c. route 3: Maluku Sea, Seram Sea, Banda Sea, Ombai Strait, and Sawu Sea. Based on article 11 Government regulation number 36 (2002) regarding rights and obligations of foreign ships when conducting innocent passage within Indonesian waters (Peraturan Pemerintah no 36 tahun 2002). See: "Peraturan Pemerintah Republik Indonesia - JDIH — KKP." Accessed April 21, 2022. https://jdih.kkp.go.id/peraturan/pp-36-2002.pdf.

[34] Article 16, Law number 6 (1996). In bahasa, pasal 16, Peraturan Pemerintah nomor 6 tahun 1996. It states that "Kapal asing bertenaga nuklir dan kapal yang mengangkut nuklir atau bahan lain yang karena sifatnya berbahaya atau beracun, apabila melaksanakan hak lintas damai harus membawa dokumen dan mematuhi tindakan pencegahan khusus yang ditetapkan oleh perjanjian internasional." See: Informasi, Sub Bagian Data dan. "Badan Pembinaan Hukum Nasional." BPHN. Accessed April 22, 2022. https://bphn.go.id/. The sentences in bahasa are very similar or identical with the translation of article 23 of UNCLOS 1982 regarding Foreign nuclear-powered ships during innocent passage.

[35] Article 9 government regulates archipelagic sea lane passage in Government regulation number 37 (2002) regarding rights and obligations of foreign ships and aircrafts when conducting archipelagic sea lane passage within designated archipelagic sea lanes. In Bahasa, it states that "Kapal asing bertenaga nuklir, atau yang mengangkut bahan nuklir, atau barang atau bahan lain yang karena sifatnya berbahaya atau beracun yang melaksanakan Hak Lintas Alur Kepulauan, harus membawa dokumen dan mematuhi Tindakan pencegahan khusus yang ditetapkan oleh perjanjian internasional bagi kapal-kapal yang demikian." See: PP No. 37 tahun 2002 Tentang Hak Dan Kewajiban kapal

There is no difference between merchant vessels, government ships, or warships. These regulations resemble Article 23 of UNCLOS 1982 regarding foreign nuclear-powered ships conducting innocent passage. It means that Indonesia governs foreign nuclear-powered ships when conducting archipelagic sea lane passage with innocent passage rules of the convention. Meanwhile, the available routes for innocent passage are the same as the three archipelagic sea lanes and cannot use other straits or waterways within the archipelago (see Figure 4). In other words, practically, there is no innocent passage for foreign nuclear-powered vessels, and the archipelagic sea lane passage for foreign nuclear-powered ships is downgraded to an innocent passage within the meaning of article 23 UNCLOS 1982. Another regulation is Commander of the Indonesian National Armed Forces Verdict number: skep/645/VII (1999). In article five, it states that:

"Foreign nuclear-powered warships during archipelagic sea lane passage should inform the Indonesian government (which is the Commander of the Indonesian National Armed Forces) beforehand for navigational safety."[36]

However, this rule is only hortatory without any obligation for prior notification. The suggestion to provide prior notification in the verdict is likely a relic of the draft article at the beginning of the UNCLOS 1982 negotiation process. At that time, there was a so-called A.S.G. Caracas draft article. One of its paragraphs stated:

"Prior notification of the archipelagic state is required of vessels that are nuclear-powered or carrying nuclear weapons or other dangerous substances."[37]

It can be concluded that, based on Indonesian regulation, foreign nuclear-powered warships can only pass through designated archipelagic sea lanes (which resemble four routes for innocent passage). See Figure 4. Those nuclear-powered warships must carry documents and follow generally accepted international rules of special precaution measures. Still, without any technical guidance on how to enforce those rules (there is no precedent that the Indonesian government has ever enforced regulations requiring the carrying of documents and following generally accepted international rules of special precaution measures)., there is also a hortatory regulation to give prior notification to foreign nuclear-powered warships before or during conducting passage.

Based on those rules, Australia's future nuclear-powered submarines shall navigate only within those designated archipelagic sea lanes (the same as four routes designated for foreign nuclear-powered vessels' innocent passage, see figure 4), but with restriction on innocent passage similar to article 23 of the convention. Australian nuclear-powered submarines shall bring documents and obey generally accepted international rules of special precaution measures while transiting Indonesian archipelagic sea lanes. It is unclear how the Indonesian government has consistently upheld this rule for foreign warships. How technically, Indonesia checks the documents of foreign warships while transiting within its archipelagic sea lanes. The last thing is that Australia's future nuclear-powered submarine may provide prior notification, which is unlikely because of the secret nature of submarine operations.

One incident that takes precedence in dealing with the issue of foreign nuclear-powered warship routes was the Bawean incident in 2003[38]. In this incident, a U.S. aircraft carrier, U.S.S. Carl Vinson, a nuclear-powered vessel, passed through the Java Sea from west to east, which is outside the permitted innocent passage routes by the Indonesian government for nuclear-powered ships and also outside the designated archipelagic sea lanes[39]. There are no other publicly available incidents regarding this topic. From this incident, we can draw some lessons to apply to Australia's future nuclear-powered submarines. While conducting aircraft operations, the U.S.S. Carl Vinson, a foreign nuclear-powered vessel, navigated through archipelagic waters outside the designated routes by Indonesia.

From the standpoint of the United States, the U.S.S. Carl Vinson was subject to an archipelagic sea lane passage regime based on Article 53 (**??**), which states that if an archipelagic state has not designated its archipelagic sea lanes (which Indonesia has only done partially), then all routes usually used for international navigation will be considered archipelagic sea lanes. It means that the U.S.S. Carl Vinson can legally pass through, even launching and recovering aircraft. Meanwhile, the Indonesian government viewed the U.S.S. Based on her route and position, Carl Vinson's passage is within the innocent passage regime. It means that she challenged two Indonesian rules. The first is a rule regarding the route of a foreign nuclear-powered vessel conducting innocent passage within Indonesian waters.

Foreign nuclear-powered vessels are prohibited from pass-

Dan Pesawat udara asing Dalam Melaksanakan hak Lintas Alur Laut Kepulauan Melalui Alur Laut Kepulauan Yang ditetapkan [JDIH bpk ri]. Accessed April 22, 2022. https://peraturan.bpk.go.id/Home/Details/52448. The sentences in bahasa are also very similar or identical with the translation of article 23 of UNCLOS 1982 regarding Foreign nuclear-powered ships during innocent passage (not archipelagic sea lane passage).

[36] Skep Panglima TNI Nomor: Skep/645/VII tahun 1999, 19 persyaratan melalui ALKI yang harus dipatuhi oleh kapal dan pesawat udara yang melaksanakan hak lintas ALKI. In English: Commander of the Indonesian National Armed Forces Verdict number: skep/645/VII (1999), 19 rules of Indonesian archipelagic sea lanes that has to be obeyed by ships and aircrafts conducting archipelagic sea lane passage.

[37] Draper, Jack A. "The Indonesian archipelagic state doctrine and Law of the Sea: Territorial grab or justifiable necessity." In Int'l L., vol. 11, p. 155. 1977.

[38] In this incident, U.S.S. Carl Vinson was at Java Sea, transiting from west to east outside four routes of innocent passage (which is the same as archipelagic sea lanes) which were provided for nuclear-powered vessel. The aircraft carrier also launched aircrafts while transiting. See: Bateman, Walter Samuel Grono. Security and the law of the sea in East Asia: navigational regimes and exclusive economic zones. Oxford University Press, 2006. Also see: Dirwan, A. "Analisis Masalah Pengaturan Ruang Udara Di Atas Alur Laut Kepulauan Indonesia (ALKI)." Jurnal Teknologi Kedirgantaraan 6, no. 1 (2021).

[39] This incident is well known for the launching of aircraft from aircraft carrier while transiting the Java Sea, outside those three archipelagic sea lanes. There are several issues regarding this incident. The first one is the issue of west-east archipelagic sea lanes, which is about the partial designation of archipelagic sea lanes to the IMO in 1996. The second issue is about the interpretation of "normal mode" during archipelagic sea lane passage, whether it includes launching/ recovering aircraft or not, and how far the aircraft can go. The last one is the issue of nuclear-powered vessel, which navigate outside the permitted routes by Indonesian government.

ing through other than the four designated routes. The second one, she violated the innocent passage rule by launching aircraft while conducting innocent passage (because it was conducted outside of designated archipelagic sea lanes). Suppose we apply this to future Australian nuclear-powered submarines. In that case, the potential incident will occur if those submarines navigate outside four foreign nuclear-powered vessel routes identical to Indonesian archipelagic sea lanes. It is worth noting how Indonesia will deal with an Australian nuclear-powered submarine. When Indonesia dared to intercept U.S. navy aircraft, let alone an Australian nuclear-powered submarine, when she navigated outside the routes that had been provided by Indonesia[40].

5. Another Related Issue: Unresolved East-West Archipelagic Sea Lane.

One unresolved issue regarding archipelagic sea lanes is whether the current archipelagic sea lanes are enough. Indonesia is the only archipelagic state in the world that has already designated its archipelagic sea lanes. In May 1996, Indonesia submitted a "partial submission of archipelagic sea lanes" to the International Maritime Organization (I.M.O.)[41] . During the submission, there was a heated discussion between maritime states, particularly the U.S. and Australia, on the one hand, and Indonesia, as a coastal state, on the other hand[42]. The point of contention is Article 53(4), which states that archipelagic sea lanes must include all routes normally used for navigation[43]. At the time, Indonesia only submitted three north-south archipelagic sea lanes to the International Maritime Organization (I.M.O.). Maritime states believe that it should be more than three[44].

However, both states have different views when the U.S. and Australia present the routes that are normal for navigation within the Indonesian archipelago. It means that the term "routes normally used for navigation" is subjective by nature, depending on which state's view it is. But there is one similarity between the U.S. and Australia. Both states want at least one more archipelagic sea lane from west to east. Before Indonesia submits another archipelagic sea lane, the U.S. stance is that the U.S. can use all routes usually used for international navigation based on Article 53 (12) UNCLOS 1982. This stance caused some incidents. One of the more prominent incidents was the Bawean incident in July 2003. In this incident, the U.S.S. Carl Vinson, a U.S. Navy aircraft carrier, went into "normal mode" by launching and recovering aircraft while conducting passage within "routes normally used for navigation." From the U.S. perspective, the aircraft carrier was conducting an archipelagic sea lane passage from the archipelago's western part to the archipelago's eastern part. However, from the Indonesian perspective, since the aircraft carrier was outside designated archipelagic sea lanes, she was conducting an innocent passage in which launching and recovering aircraft was prohibited.

Just like the Bawean incident, which involved an aircraft carrier, other forms of "normal mode" incidents can also happen to submarines in a scenario when in the future, Australia's nuclear-powered submarines navigate from the middle part of the Indonesian archipelago to the eastern part of the archipelago, then Australia and Indonesia will have a different view. Assuming the normal mode for submarines is submerging, then from the U.S. and Australia's perception, subs are permitted to submerge from west to east of the archipelago. From Indonesia's perception, she shall surface and show her flag during the passage since it is considered an innocent passage. There is also another requirement for nuclear-powered submarines. The nuclear-powered submarine shall carry documents and follow preventive measures based on article 23 of UNCLOS 1982 while conducting innocent passage.

6. Submerged Passage of Nuclear-Powered Submarine Under Archipelagic Sea-lane during Peacetime.

One of the biggest potential problems regarding Australia's new submarines will be the interpretation of "normal mode." If it were accepted that the normal mode for subs is submerging as *lex lata*, then Australia would have many advantages. But for Indonesia, it will have a detrimental effect. The situation and conditions for archipelagic states differ from those for strait states bordering international straits. While the archipelagic state accepts the interpretation of normal mode for submarines as submerging, it will still bear a significant loss, especially in some circumstances below.

First, by having transit with submerging, submarines will have a massive chance to deviate from the archipelagic sea lane axis without coastal state knowledge. Therefore, it will violate the coastal state's sovereignty. In a scenario when one submarine passes through an archipelagic sea lane by submerging, there is no way Indonesia can check whether that submarine obeys the coastal state's archipelagic sea lane axis or not. This is particularly true considering the underwater surveillance capability that Indonesia has. Even if Indonesia has acquired supreme underwater surveillance ability by acquiring modern technology from significant powers such as China, it will be challenging to detect Australia's nuclear-powered submarine, considering its vast area of archipelagic waters. Australia's nuclear-powered submarine can use second or third archipelagic

[40] However, the problem is that it is extremely difficult to detect a cutting-edge technology of new nuclear-powered submarines, especially considering Indonesian capability to conduct underwater surveillance.

[41] IMO is considered a "competent international organization" based on UNCLOS 1982 article 53 (9). See: Forward, Chris. "Archipelagic sea-lanes in Indonesia-their legality in international law." Austl. & NZ Mar. LJ 23 (2009): 151.

[42] Read: Puspitawati, Dhiana. "The east/west archipelagic sea lanes passage through the Indonesian archipelago." Maritime Studies 2005, no. 140 (2005): 1-13.Also read: Johnson, Constance. "A rite of passage: The IMO consideration of the Indonesian archipelagic sea-lanes submission." The International Journal of Marine and Coastal Law 15, no. 3 (2000): 317-332.

[43] See: Kumala, Masitha Tismananda, and Dina Sunyowati. "Designation of Archipelagic Sea Lanes according to the United Nations Convention on the Law of the Sea 1982 (Indonesia Archipelagic Sea Lanes Case)." International Journal of Business, Economics and Law 10, no. 48-54 (2016).

[44] The U.S. has its own presentation of routes which are considered "normally used" for international navigation. Meanwhile, Australia also has its own version of routes "normally used" for international navigation. But the similar thing between the U.S. and Australia version is a traversing route from west to east archipelago.

sea lanes as entrance points in the south. Once the sub is within the archipelagic sea lane, she can sail by submerging unstoppable from Borneo Island to Papua Island in the east. This is because these areas' relatively deep seas of archipelagic waters are suitable for submarine operations.

The second one, submerging, will have an issue with the environment in case there is an accident below the water. This is especially true for nuclear-powered submarines. Nuclear power has always become an environmental concern. Any issue or nuclear incident will have an impact on the coastal state. According to articles 54 and 42(1) UNCLOS 1982, the coastal state can regulate pollution and navigation safety. However, how can the coastal state check the obedience of a submarine if the nuclear-powered submarine can legally pass through an archipelagic sea lane by submerging? If something happens to Australia's submerged nuclear-powered submarine that causes a nuclear radiation catastrophe, it will become an environmental disaster for the coastal state. There was a case when the U.S. nuclear-powered submarine of the Seawolf class hit an underwater object in the South China Sea[45]. Because of the secrecy concern, the U.S. government did not provide the exact accident location. It is not ruled out that the accident may have taken place within Indonesian archipelagic waters. Nobody knows since it is almost impossible for Indonesia to check the situation. In a scenario where such an accident happens while submerging under an archipelagic sea lane, the coastal state will bear the burden of the radioactive issue. In the case of the Soviet nuclear-powered submarine, Komsomolets, there was a radioactive leakage found years after it sank[46]. If something happens to the nuclear reactor, it could become an environmental disaster. When a submarine causes pollution, it is impossible to know which sub-caused it while navigating below the waters.

The third one, based on articles 54 and 42(1) UNCLOS 1982, is that the coastal state can make regulations regarding the safety of navigation. When the coastal state makes a traffic separation scheme within an archipelagic sea lane, it is extremely difficult for the coastal state to check whether submarines that pass underwater obey the rule. Even though it is arguable that the coastal state created the traffic separation scheme to regulate submerged passage. However, in some cases, when, for example, there is a diving operation in a strait or cable and pipeline work, and the submarine does not obey the safety of navigation, the consequences will be detrimental. Until now, there has been no special safety navigation regulation for submarines passing through archipelagic sea lanes while submerging. Of course, when an archipelagic state makes such a regulation, it is a sign that the archipelagic state accepts the interpretation of the submarine's normal mode, including submerging passage. However, this regulation is important to prevent collisions between submarines, collisions between submarines and surface vessels, or to prevent submarines from hitting underwater objects, such as underwater mountains and shipwrecks. This is because a submarine is like a blind man who cannot see anything but hear.

7. Submerged Passage of Nuclear-Powered Submarine Under Archipelagic Sea Lane in Times of Armed Conflict.

The next one is that, in times of armed conflict, there is a vast opportunity for belligerent state submarines to use archipelagic waters as a sanctuary and a place for procrastinating. In times of war, the laws of naval warfare and the direction of the sea are mutually exclusive. In other words, both bodies of law apply. Based on the San Remo Manual (S.R.M.), which is a codification of the Law of Naval Warfare by experts in 1994, in article 28, the San Remo Manual supports the interpretation that during armed conflict, belligerent submarines can pass through a neutral state's archipelagic sea lanes by submerging. A neutral archipelagic state cannot close sea lanes for belligerents[47]. In times of armed conflict (in this context, an International Armed Conflict), archipelagic sea lanes passage continues to apply[48]. On the other hand, based on paragraph 17 of the San Remo Manual, belligerent states cannot use a neutral state's archipelagic waters as a sanctuary, nor can they use a neutral state's archipelagic waters as a place for battle[49].

However, since belligerent submarines can pass through the archipelagic sea lanes by submerging, archipelagic states can't control their archipelagic waters so as not to be used by belligerents. This is because there is no opportunity for the coastal state to detect and identify submarines that pass through its archipelagic sea lanes. By doing submerged passage, the coastal state cannot check how long that specific submarine has been within the archipelagic sea lane. There is also the possibility that the submarine deviates from the archipelagic sea lane. Based on the San Remo Manual of 1994, belligerent ships cannot use the territorial waters or archipelagic waters of neutral states as a place of sanctuary. When the neutral coastal state cannot act, the opponent state will operate by itself. Archipelagic waters can become a place of hostility between belligerents.

This is especially dangerous in the case of Australia's nuclear-powered submarines. Australia is facing China's threat by having a nuclear-powered submarine. China said that since Australia uses nuclear-powered subs, it will lose its privilege not to be attacked by submarine weapons[50]. This is because China cannot trust its potential adversaries to not use its capabilities to the maximum that they can get, especially in security matters.

[45] ABC News. "Sailors on US Nuclear Sub Injured after Collision in South China Sea." ABC News. ABC News, October 8, 2021. https://www.abc.net.au/news/2021-10-08/us-nuclear-sub-hits-object-south-china-sea/100523164.

[46] Read: Montgomery, George. "The Komsomolets Disaster." Inside CIA: Lessons in Intelligence (2004): 6. Also read: Flo, Janita Katrine. "Radioactive contamination in sediments near the sunken nuclear submarine Komsomolets, SW of Bear Island in the Norwegian Sea." Master's thesis, The University of Bergen, 2014.

[47] Paragraph 29 of SRM

[48] Paragraph 27 of SRM

[49] Paragraph 17 of SRM

[50] "'Brainless' Australia a Target for 'Nuclear War', Warns ..." Accessed April 22, 2022. https://www.news.com.au/technology/innovation/military/brainless-australia-a-target-for-nuclear-war-warns-top-china-expert/news-story/4652ab802a01b677c6df6de51479bd8d.

This will force China to send its Ship Submersible Ballistic Nuclear (SSBN) toward Australia. The best way to get to Australia is by passing through the Indonesian archipelagic waters.

In contrast, Australia will send attack submarines to monitor Chinese SSBNs in the archipelago. From Australia's perspective, it is better to counter its enemy while far from home. All of these will result in the use of archipelagic waters as a place to hide and seek Indonesia's neighbors' submarines. Belligerencies will also likely occur within archipelagic waters since Indonesia lacks the capacity to control them underwater. In this way, Indonesia will bear the cost of the spillover effect of the armed conflict between China and Australia. Not to mention when the hostilities in Indonesian waters result in the damage of SSN or even SSBN, which will significantly impact the environment.

War is all about the first move. Those who have the first move will have a considerable advantage, especially regarding the element of surprise. In a scenario where Australia is hostile to China, Australia's submarine will try to use archipelagic waters as a sanctuary and a place for procrastinating to get a tactical advantage in the first place. By doing submerged passage, the coastal state cannot check how long a submarine has already been within its archipelagic sea lane. Australia's submarine might also deviate from the archipelagic sea lane to find a place for sanctuary within the coastal state's archipelagic waters. However, it will only take advantage before the opponent state realizes this. Once the opponent is aware of this situation, Australia will stop taking advantage of it. This is because when the neutral coastal state cannot act, the opponent state will function by itself. By this time, Australia will have already stopped using archipelagic waters as a sanctuary or lingering under archipelagic sea lanes; otherwise, the opponent state can act by itself and attack Australia's submarine within a neutral archipelagic state.

In a scenario where Indonesian waters are used as a maritime battleground, these nuclear-powered submarines can go into many places undetected and attack many of the archipelagic state's coastal cities, including Indonesia's new capital city.

Since immemorial, the capital city has always been the crown jewel of a state. During warfare, the capital city is the one that becomes the main target of the enemy[51]. Once the capital city can be conquered, usually, the state will lose the war, even though, in some cases, there are so-called governments in exile[52]. Different from the old capital city of Jakarta, the future capital city of Indonesia will be much more disaster-proven. However, it will be much more vulnerable to the threat from the sea. It is especially true considering the location of the new capital city, which is on the coast of a deep and wide strait that is part of an Archipelagic Sea Lane, the playground for the neighbor's submarine.

In August 2019, Indonesia announced that it would move its capital city. Its present capital city, Jakarta, has already passed its sustainable limit for supporting its residents' lives[53]. The Indonesian government selected Penajam Paser Utara city, a countryside located on the east coast of Borneo Island, as the new capital city (see Figure 1)[54] . Unlike Malaysia and Australia, which moved their capital cities landward, the new Indonesian capital city seems to be the same coastal city as the previous one[55]. As we can see from Figure 2, Makassar Strait is a deep and wide strait. Makassar Strait, which extends from north to south, has a depth variation of hundreds of meters to a thousand meters, with the deepest reaching more than two thousand meters.

Meanwhile, it has the shortest width of around fifty-seven nautical miles in the northern part of the strait. From the tactical point of view of naval warfare, it means that this area is suitable for submarine areas of operation[56]. This is different from Jakarta, in which, even though it is in a coastal area, the water is shallow and congested (see Figure 3). It is impossible to operationalize a submarine in shallow and crowded waters near the off-Jakarta coast (see Figure 3).

Even though Jakarta has many problems maintaining its status as a capital city, in terms of submarine threats, it is much safer than its future successor. Jakarta is located far from the deep sea, which can become a submarine area of operation (see Figure 3). Jakarta is in a coastal area of the Java Sea, a sea that was part of Sundaland in the past[57]. The depth of the Java Sea around Jakarta is only a little less than 50 meters (see Figure 3). It is impossible for submarines, especially nuclear-powered submarines, which can carry sub-surface-to-land missiles, to operate there. The closest a submarine can get by submerging is to the Indian Ocean, which is more than 200 KM away. After all, the Indian Ocean is located across Jakarta, making it more challenging to get attacked by cruise missiles from sea to land[58].

[51] During many wars, capital city is main target of capture, conquer, or in the least form, terror. For example, during World-War II, once Germany subdued Paris, France was considered defeated. Germany also targeted London to spread terror. The U.S. also targeted Tokyo for terror in a famous operation called Doolittle Raid. In modern day, Russia targeted Ukraine's capital city Kiev.

[52] Several examples: France during World-War II, led by Charles de Gaulle, Indonesia during Dutch Politionele acties, or even Nationalist China by Chiang Kai Sek who govern China mainland from Taiwan.

[53] Guest, Peter. "The Impossible Fight to Save Jakarta, the Sinking Megacity." WIRED UK, October 15, 2019. https://www.wired.co.uk/article/jakarta-sinking.

[54] Maulia, Erwida. "Jokowi Announces Indonesia's New Capital in East Kalimantan." Nikkei Asia. Nikkei Asia, August 26, 2019. https://asia.nikkei.com/Politics/Jokowi-announces-Indonesia-s-new-capital-in-East-Kalimantan.

[55] Australia moved its capital city several times from Sydney to Melbourne, and now Canberra. Malaysia moved its capital city from Kuala Lumpur to Putrajaya. Both states moved capital cities landward from the previous capital city which were port cities. Indonesia on the other hand choose Penajam Paser Utara which is also coastal city same as Jakarta.

[56] Submarine, especially nuclear-powered submarine which have relatively huge body compared to its conventional counterpart, can only operate in a wide and deep area.

[57] Read: Bird, Michael I., David Taylor, and Chris Hunt. "Palaeoenvironments of insular Southeast Asia during the Last Glacial Period: a savanna corridor in Sundaland?." Quaternary Science Reviews 24, no. 20-21 (2005): 2228-2242.

[58] The farther the distance, the more difficult it will be to target an object. This is because the chance to get monitored will be bigger. Then the chance for the missile to be destroyed by anti-missile defence will be higher.

One of the new capabilities that Australia's nuclear-powered submarine has is the ability to attack land targets from sub-surface by acquiring Tomahawk missiles from the United States[59]. Based on San Remo Manual paragraph 26, when the coastal archipelagic state is at war, it cannot close its archipelagic sea lanes. The archipelagic sea lane passage still applies in times of armed conflict, including for neutral submarines. A neutral sub still has the right to submerged passage even though the archipelagic state is at war with another state. This rule will significantly contribute to Australia's ability to win the war. Australia's nuclear-powered submarine can go through the entrances of the second or third archipelagic sea lanes. It would be much better to observe and wait for other neutral states' submarines that also want to pass through archipelagic sea lanes. Then pass the entrance almost simultaneously as the neutral state's submarine.

This is because there is a hortatory San Remo Manual rule which suggests neutral states inform the belligerent archipelagic state before conducting archipelagic sea lane passage. However, since it is a hortative rule, it is unlikely that neutral conditions will uncover their secret submarine position in Indonesia. Not to mention submarines from "qualified neutrality" states that support Australia without becoming a party to the armed conflict[60]. If this rule were mandatory, there would be no chance for Australia to get this substantial strategic advantage. This is because Indonesia will be aware of all neutral submarines that pass through the entrance of archipelagic sea lanes and will leave unreported subs as a target. Once Australia's nuclear-powered submarine has passed through the opening, then it will be much easier to choose and target coastal cities in Indonesia, including the new capital city, which is located on the coast of Makassar Strait.

One of the most logical and affordable solutions for the coastal state is using anti-submarine mines. However, the blast of the nuclear-powered submarine itself could become a disaster for the coastal state. Not to mention the explosion's impact on other ships underway on their archipelagic sea lane passage. It's the same as blowing up your adversary inside your own home. In other words, once the enemy's nuclear submarine passes through archipelagic sea lanes, the coastal state cannot do anything. At best, it calculates collateral damage, proportionality principles, and military necessity at its own cost ahead of time.

8. Nuclear - Powered Submarines and Potential Regional Arms Race.

It may be true that Indonesia and Australia have no intention of fighting, but who knows what will happen in a few years when international geopolitics and internal politics in both countries have changed. From a realistic point of view, in global power politics, many times in history, the growth of power was followed by a change of attitude due to the expanding ambition of the rising power. The increasing power will demand better treatment and respect from its neighbors.[61] The one considered unthinkable today might be a logical decision in the future. Once Australia has all its nuclear-powered submarines with many other armaments and its military might, as a result of the AUKUS alliance, it will treat its neighbors differently. Australia will position itself differently from its regional counterparts.

It is impossible for Australia today to conduct Freedom of Navigation Operations (FONOPS) to challenge its neighbors as the U.S. does. Still, it might be performed when it has a much stronger position. There is a chance that Australia will challenge the hurdle of navigation across the Indonesian archipelago that it has borne before. On the other hand, the rising power will increase the anxiety of its immediate neighbors. As a result, there is a possibility that an incident will happen in the future when Australian nuclear-powered submarines challenge Indonesian authorities regarding the "four-designated innocent passage routes for foreign nuclear-powered vessels" and the "partial submission of archipelagic sea lanes" by having a submerged passage from west to east or east to west of the archipelago. Meanwhile, Indonesia will feel more threatened because of Australia's drastic increase in military capability due to the acquisition of nuclear-powered submarines.

From the theory of threat perception, the threat is always seen as a result of capabilities multiplied by intention[62]. The more capabilities your neighbor has, without any change from the "intention" factor, the higher the threat perception. It means the increase in Australia's capacity by acquiring nuclear-powered submarines will significantly escalate threat perception. Moreover, new threat perception theories add other approaches, one of which is the vulnerability-based approach[63].

[59] There was also a planning to acquire sub-surface to land missile from Collins class submarine before, but it was cancelled. Australia decided the new capability to attack land will be put in new submarine. Just like the U.K's Astute class and the U.S.'s Virginia class, Australia's future nuclear-powered submarines will also carry tomahawk cruise missile for surface and land target. See: Patrick, Aaron. "Australia's Eight Nuclear Subs Will Be Designed to Outclass China." Australian Financial Review, September 16, 2021. https://www.afr.com/policy/foreign-affairs/australia-s-eight-nuclear-subs-will-be-designed-to-outclass-china-20210916-p58s1n

[60] A state is considered "qualified neutrality" when it is not belligerent, but it supports one party of the conflict indirectly. See: Dinstein, Yoram. War, aggression, and self-defence. Cambridge University Press, 2017.

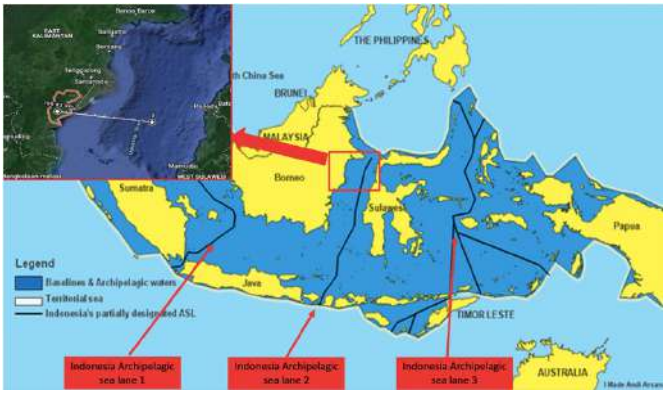
[61] In this case, Australia's attitude towards its neighbours might be changed after it has "a new bigger muscle" in the future. A realism perspective of international relations, especially structural realism, and neo-realism. Read: Mearsheimer, John J. "Structural realism." International relations theories: Discipline and diversity 83 (2007): 77-94.Also read: Donnelly, Jack. Realism and international relations. Cambridge University Press, 2000. Also read: Shimko, Keith I. "Realism, neorealism, and American liberalism." The Review of Politics 54, no. 2 (1992): 281-301.

[62] See: Singer, J. David. "Threat-perception and the armament-tension dilemma." Journal of Conflict Resolution 2, no. 1 (1958): 90-105.

[63] Threat perception of vulnerability-based approach for state actor. In his Ph.D. dissertasion, the writer provides an example of vulnerability-based approach for state actor. He mentions about the U.S. threat perception towards Soviet Union during cold war. Because the U.S. had vulnerability of nuclear attack from Soviet Union, then the threat perception would increase. See: Vandepeer, Charles. "Rethinking threat: intelligence analysis, intentions, capabilities, and the challenge of non-state actors." PhD diss., (2011): 137.

Having a new capital city located in a location vulnerable to submarine attack will relate to the supposed threat from Australia, which is the closest neighbor that can attack it. Having a new capital city prone to submarine attacks will likely increase the threat perception from Indonesia to Australia in the future. A foreseeable impact soon is that a regional arms race will happen. Also, having an incident of finding Australia's nuclear-powered submarine submerged under Indonesian straits and waterways outside those three archipelagic sea lanes, especially within the east-west axis, will likely increase Indonesia's threat perception towards Australia. But Australia's submarine is not the only one that can threaten Indonesia in the future concerning its new capital city. Many other nuclear-powered submarines from several countries will go back and forth right before Indonesia's new capital city. Australia needs to keep the "intention" factor low to get the best result in threat perception for both states. Confidence Building Measures (CBM) are one of the solutions to reduce the threat perception between both countries and to nullify the spiral effect of an arms race.

Figure 1: Location of Indonesia's new capital city at the coast of Makassar Strait which is part of Indonesia Archipelagic Sea Lane 2.

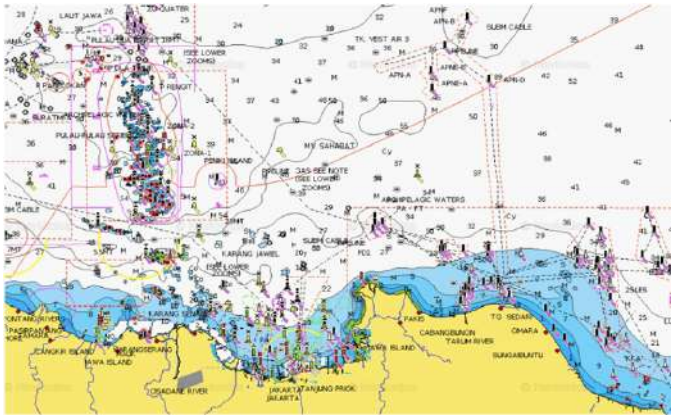


Source: Authors.

Figure 2: Makassar Strait as a deep and wide strait, which is part of second Indonesia Archipelagic Sea Lane.

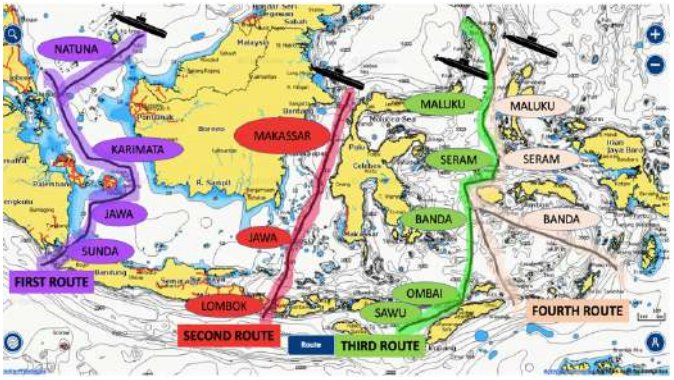
Source: Authors.

Figure 3: Jakarta is located at a shallow and congested coastal city which is safe from submarine threat.



Source: Authors.

Figure 4: (Maritime chart from Navionics chart, with changes by the author): Four innocent passage routes for foreign nuclear-powered vessels based on Government regulation 36 (2002), which resemble partial designation of Indonesian archipelagic sea lanes.



Source: Authors.

Conclusions

The article concludes that the potential ramifications of AUKUS nuclear-powered submarines towards Indonesia's right to implement its archipelagic state status must be fully realized and anticipated. In particular, Indonesia's interpretation of innocent passage routes for foreign nuclear-powered submarines, partial designation of archipelagic sea lanes, and the "normal mode" interpretation for submarines when conducting archipelagic sea lane passage needs to be taken into consideration by both Indonesia and Australia in regards to the development of nuclear-powered submarines as part of the AUKUS agreement. Despite the fact that realization of Australia's nuclear-powered submarines program as part of AUKUS will not be fully operational by early and mid-2030's. The relevance of enhanced confidence-building measures at senior officials' level between defense and security officials between both countries is required, to avoid potential misunderstanding and miscalculation. This is

imperative to minimize its potential fallout towards the durability of Indonesia-Australia maritime defense and security relations. The full comprehension of these potentialities needs to be fully realized as to minimize the potential miscalculation between threat perception and intentions between both countries.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 12–18

ISSN: 1697-4840, www.jmr.unican.es

Basic Characteristics for Development of Antenna Systems for Mobile Satellite Communications (MSC)

Dimov Stojce Ilcev[1,*]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 24 Jun 2023;
accepted 16 Jul 2023.

Keywords:
MSC, SES, AES, GES, VDV, MES, MMSC, LMSC, AMSC, MSA, GNSS, LGA, G/T. EIRP, GEO, LEO, VSAT, Mechanical and Electrical Characteristics, Basic Relations, Bandwidth, Gain.

ABSTRACT

More then one century ago was developed first radio and used onboard ship for communication and safety purposes. Namely, Mobile Satellite Communication (MSC) systems were conceived for the transmission and receiving of telegraphy and telephony signals via mobile antenna at first from ships, and then from cars, trains and aircraft. The consideration of antenna transmission is inevitable, especially in MSC systems, where their propagation characteristics are much affected by different and changeable local environments during movement of mobile and differ greatly from those observed in fixed satellite systems. To create adequate antenna hardware design for MSC systems, engineers have to consider all related factors in order to realize full mechanical and transmission potentials. This article describes evolution and development of mobile antenna systems, classification and types, and characteristics of MSC for Ship Earth Station (SES) and Aircraft Earth Station (AES).

1. Introduction.

The antenna system used for any mobile satellite communication platform is one of the critical and least important parts of the Mobile Satellite Communication (MSC) network. The mobile satellite antenna platform is the interface between the satellite equipment and the external environment to connect ships, land vehicles (road and rail) and aircraft with customers via Ground Earth Stations (GES) or Gateways. Thus all global MSC systems require antennas at the transmitter and receiver to operate properly.

In essence, a satellite antenna enables transmission of Voice, Data and Video (VDV) to a Mobile Earth Station (MES) or receiving data from mobiles regardless of the different positions on the surface of the globe of the two MSC stations. The other satellite stations can be a shore office connected via GES terminals or other mobile stations. All satellites used in MSC networks make use of a beam, which is a pattern of electromagnetic waves transmitted by the satellite. The MES antenna transmission via satellite transponders has a defined pattern and the beam can be wide or narrow covering a large or small area on Earth.

The antenna systems onboard MES terminals are stationary due to the constant movement of the mobile when it is in motion and therefore require the dish to be movable in all dimensions. The dish itself is hidden from view by the radome cover but viewed up close they are sophisticated pieces of equipment with motors and and gears that allow the antenna to maintain a lock on the satellite in all but the most severe conditions. This can be overcome by making use of mobile antenna systems with automatic pointing a satellite dish in relation to azimuth and elevation in the direction of the satellite. The goal of both of these directions for the satellite is to optimize the signal strength so that MES antenna has the best signal and can use the satellite service uninterrupted.

Mobile antenna positioning or tuning is very important aspect for getting standard broadcast signals from a satellite. Thus, the mobile satellite antenna must be automatically pointed at a precise angle to get the strongest possible signal. If the mobile

[1]University of Johannesburg, Johannesburg, South Africa.
[*]Corresponding author: Dimov Stojce Ilcev. E-mail Address: ilcev@uj.ac.za.

antenna position is adjusted manually, it became too difficult to align it at the optimum position.

2. Evolution of Antenna Systems for placeMobile Radio communications.

The Russian professor of physics Alexander Stepanovich Popov designed his first world's radio receiver in 1895 with antenna in the shape of wire mounted on a balloon in the air and transmitter with a lightning conductor as an antenna, including a metal filings coherer and a detector element with telegraph relay and a bell. Soon later, Marconi started commercially to deploy radio and antenna equipment on board different merchant ships and to establish his own company for the production of maritime radio and antenna equipment.

Figure 1: Communication, Navigation (GNSS) and Broadband Shipborne Antennas.

Source: Author.

Since the initial use of mobile radio, more than 100 years ago, was for long distance wireless communications at LF and the first shipboard antenna were all made of haphazard lengths of wire strung as high as possible above the ship's topside, evidently the thinking was that the longer and higher the wire, the better the results should be. After those different kinds of wire and whip antennas were developed for MF/HF/VHF Maritime Mobile Satellite Communications (MMSC), Land Mobile Satellite Communications (LMSC) for personal and vehicle communication and Aeronautical Mobile Satellite Communications (AMSC).

3. Classification & Types of Mobile Satellite Antennas (MSA).

The general classifications of MSA in connection with the service operators and providers are performed on the following shipborne major types: satellite communications antennas, integrated GPS and GLONASS Satellite Navigation Antennas (GNSS) and satellite broadband (multimedia) antenna systems shown in **Figure 1.** In **Figure 2** are shown vehicle borne satellite communicator, GNSS and broadband antenna systems, which can be installed onboard road and rail vehicles.

However, the fundamental classification of MSA systems, according to gain values and technical characteristics, falls into three major groups as follows: Low-Gain Omnidirectional Antennas; Medium-Gain Directional Antennas and High-Gain Directional Aperture Antennas.

4. Antennas Requirements and Technical Characteristics.

This section describes important general requirements for mobile antenna solutions used in MSC systems for maritime, land (road and rail) and aeronautical applications, including antennas for personal handheld terminals. At any rate, the mobile antenna has to be compact, flexible and lightweight and perform with good mechanical and electrical characteristics, especially for heavy mobiles such as ships and aircraft, owing to the special conditions of installation and the influence of changeable environmental conditions.

4.1. Mechanical Characteristics.

Mobile antennas have to satisfy the requirements of mechanical characteristics in relation to construction strength and easy installation. In fact, easy installation and appropriate physical shape are very important requirements in addition to compactness and lightweight. In the case of shipborne antennas, the installation requirements are not as severe compared to that of aircraft and cars because even in small ships there is a comfortable space to install an antenna set.

Figure 2: Communication, GNSS and Broadband Vehicleborne Antennas.

Source: Author.

Figure 3: Communication, Navigation (GNSS) and Broadband Airborne Antennas.

Source: Author.

Otherwise, the only problem is because all types of ships satellite antennas are sometimes under huge stress from vibration and sloping caused by strong winds, ship's rolling and pitch or is subject to corrosion by sea salt. Owing to these problems, a ship's satellite antenna has to be well protected by plastic radome and properly mounted on a strong mast, specially designed for a certain size of antenna.

In the case of road vehicles, especially small cars and buses, low profile and lightweight equipment is required. The big haulage trucks and locomotives have much space for installation of antennas, but still they need to be aerodynamically in shape. The requirements are the same for aircraft, although more severe conditions are required to satisfy avionic standards. Low air drag is one of the most important requirements for aircraft antennas. Vehicles utilizes smaller antenna, while aircraft

utilize more aerodynamic sizes of antenna. In **Figure 3** are shown airborne communication, GNSS (GPS and GLONASS and broadband antenna systems.

4.2. Electrical Characteristics.

Sometimes, the mechanical construction of antenna is perfect because of some functional or electrical characteristics; however, designers of antenna have to keep in mind that the compact design of antenna has two major disadvantages in electrical characteristics, such as low-gain and wide beam coverage. The gain is closely related to the beam width and a Low-Gain Antenna (LGA) should have a wide beam width. As the gain of antenna is theoretically determined by its physical dimensions, reducing the size of antenna means decreasing its gain.

Because of low-gain and limited electric power supply, it is very difficult for mobile antennas to have enough receiving capability known as a Ratio of System Gain to System Noise Temperature (G/T) and transmission power known as an Effective or Equivalent Isotropically Radiated Power (EIRP). These disadvantages of Mobile Earth Station (MES) can be compensated by a satellite that has a large antenna and HPA with enough electrical power.

A powerful satellite with high G/T and EIRP performance should permit the fabrication of MES with compact and lightweight antennas. The next disadvantage is that a wide beam antenna is likely to transmit undesired signals to and receive them from an undesired direction, which will cause interference in and from other systems. The wide beam is also responsible for several fading effects, such as that from sea surface reflections in MMSC and AMSC and multipath fading in Land MSC (LMSC) and so, a compact mobile antenna system is required to prevent fading and interference.

Accordingly, it is inevitable for mobile antennas not to have enough performance, such as gain, radiation power and receiving capability because of their small physical dimensions. Without consideration of this, the requirements of transmitting and receiving performance of mobile antennas mainly depend on the satellite transmission capability. The first and second generations of Inmarsat satellites have a global beam and the third generation has spot and global beams to provide global coverage.

The regional or domestic Mobile Satellite Systems (MSS), such as AMSC, MSAT and Optus have spot beams. The spot gives higher satellite capacity than global beams although there are basically no big differences between requirements for mobile antennas in the global system, such as Inmarsat or the mentioned regional systems.

5. Basic Relations of Antennas.

The basic relations of antenna systems are very important parameters to easily understand the mode of antenna functions in two-way (duplex) satellite transmission systems, such as MES transceiving antennas. Moreover, these characteristics of MES antenna systems are needed for link budget calculations and for good satellite up and downlink design, which can provide reliable and acceptable quality satellite communications. At this point, this implies that the signal transmitted via the MES transmitting (Tx) antenna must reach the receiving (Rx) antenna of other MES or Land Earth Stations (LES) at a carrier level sufficiently above the unwanted signals generated by various unavoidable sources of noise and interference.

5.1. Frequency and Bandwidth.

In almost all present and forthcoming MSC systems using Geostationary Earth Orbit (GEO) satellites, the L-band 1.6/1.5 GHz is used for a link between the satellite and MES. The required frequency bandwidth in L-band MSS is about 8% to cover transmitting and receiving channels. Otherwise, in using a narrow-band antenna, such as an omnidirectional patch antenna, some efforts have to be made to widen the bandwidth. The S and L-band are allocated in WARC-92 for the Big Low Earth Orbit (LEO) Iridium and Globalstar MSC systems, which require frequency bandwidths of about 5%.

5.2. Gain and Directivity.

The required antenna gain is determined by a link budget, which can be calculated by taking into consideration the required channel quality and the satellite capability. The channels are expressed as C/N_o and depend on the G/T and EIRP values of the satellite and MES. Thus, in the abandoned Inmarsat-P system and forthcoming ICO system, medium gains of 7 to 16 dBi are required for voice and HSD channels using a transmission speed of about 24 Kb/s. In the case of present systems such as AMSC or MSAT, Optus and similar systems using GEO constellation, a medium gain between 8 to 15 dBi is required for voice and HSD channels of 24 Kb/s.

On the other hand, in the case of the present Inmarsat-A and B MES, a comparative High-Gain Antenna (HGA) of minimum 24 dBi is required, due to the difference in satellite capabilities. Meanwhile, Low Gain Antenna (LGA) of about 0 to 4 dBi are used in the Inmarsat-C and other similar omnidirectional systems to provide (Low Speed Data (LSD) of only about 600 to 1,200 b/s.

The GPS system has adopted LGA because of the extremely low data rate of 50 b/s from the satellites. Because they have the same type of LGA system, it is possible to integrate Inmarsat-C MES with the GPS receiver. There are no exact definitions to differentiate between characteristics of Low, Medium and High-gain antenna systems, except by the gain quantum, shape of the antenna and type of service. However, in the present and upcoming L-band MSC applications, classification of L-Band MES antenna systems by their receiving and service capabilities is illustrated in **Table 1.**

Table 1: Classification of L-Band Antenna Systems in MSC.

Type of Antenna	Gain Class	Typical Gain dBi	Typical G/T dBK]	Typical Antenna (Dimension)	Typical MSC Services
Omnidirectional	Low	0 – 4	–27 to –23	Quadrifilar Drooping-dipole Patch	LSD (Messages) Ship (Inmarsat-C) Vehicles & Aircraft
Semidirectional (Only in Azimuth)	Medium	4 – 8 8 – 16	–23 to –18 –18 to –10	Array (2–4 elements) Helical, Patch SBF (0,4m Φ) Phased Array (20 elements)	Voice/HSD Ship (Inmarsat-M) Vehicles Aircraft (Inmarsat-Aero)
Directional	High	17 – 20 20 – 24	– 8 to –6 –4	Dish (0,8m Φ) Dish (1m Φ)	Voice/HSD Ship (Inmarsat-A, B)

Source: Author.

The ideal antenna gain can be defined with an isotropic (hypothetical) antenna, which has an isotropic radiation pattern without any losses and therefore radiates power in all directions in uniform intensities. Thus, if input power (P_{in}) is put into an isotropic antenna, the power flux-density per ideal unit area (P_{id}) at distance (r) from the antenna is given by the following relation:

$$P_{id} = P_{in}/4\pi r^2 [W/m^2] \quad (1)$$

However, if radiated power density is P (θ, Φ)/r^2 in directions (θ = angle between the considered direction and the one in which maximum power is radiated, known as boresight; and Φ = phase) at distance (r) from the antenna under elevation, the gain of the antenna can be defined by the following equations:

$$G(\theta,\Phi) = P(\theta,\Phi)/r^2/P_{id} = P(\theta,\Phi)/r^2/P_{in}/4\pi r^2 = 4\pi P(\theta,\Phi)/P_{in} = P(\theta,\Phi)/P_{in}/4\pi\ [dBi] \quad (2)$$

The above-defined gain is called an absolute gain or directive gain, which is determined only by the directivity (radiation pattern) of the antenna without taking account of any losses in the antenna system, such as impedance mismatch loss or spillover loss. Thus, if direction is not specified and the gain is not given a function of (θ, Φ), it is assumed to be maximum gain. There is a general relationship between absolute gain and the physical dimensions of the antenna and this is given by the equation as follows:

$$G = 4\pi/\lambda^2\ \eta a \quad (3)$$

where η = aperture efficiency and a = physical aperture, which will denote the effective aperture of the antenna. According to the above relation it can be realized that compact antennas with small apertures must have low gain. If an antenna aperture is a dish a known diameter (d), can be written in normal and in decibel expression as follows:

$$G = (\pi d/\lambda)^2\ \eta = 10.log\eta\ (\pi d/\lambda)^2\ [dBi] \quad (4)$$

Thus, it can be calculated that the gain in the Inmarsat shipborne antenna with a diameter of d = 1 m operated at 1.5 GHz is about 21 dBi. The directivity of the antenna D(θ, Φ) does not include dissipative losses and is defined as the ratio of P(θ, Φ) to the power per unit solid angle from an isotropic antenna radiation, the same total antenna radiated power (P_r). The antenna directivity can be expressed by:

$$D(\theta,\Phi) = P(\theta,\Phi)/P_r/4\pi \quad (5)$$

The definition of antenna directivity does not take the efficiency of an antenna into account because ($P_r/4\pi$) is related to the actual power launched into space. The ratio of G(θ, Φ) to D(θ, Φ) is termed the radiation efficiency of the antenna.

6. Designs of Antennas for MMSC.

The new developed MMSC systems and equipment have introduced modern complexities into the design of shipboard antennas. The direct line-of-sight between antenna and satellite requires the antenna to "see" from horizon to overhead (zenith – 90^o) in elevation and 360^o in azimuth angle, with total hemispherical coverage. In fact, this is fulfilled in the case of transceiver antenna through the use of tracking rotatable, high-gain antennas often installed in pairs on board ship to attain full coverage, irrespective of blockage in the form of the funnel, musts, stacks and other objects.

The ship platform itself imposes even more stringent requirements. Therefore, in spite of constant vibrating, pitching, rolling and yawing during bad weather conditions, the MSC antenna's narrow radiation beam must be pointed accurately from any position on the high seas. Otherwise, the situation regarding land or aero antenna is less complicated.

Figure 4: Inmarsat-FB, Global Xpress and TVRO Shipborne Antennas.

Source: Author.

As the 1970s dawned, optimism and enthusiasm about satellite communications was so great with ideas to virtually replace HF radio in the Navy with the new Fltsatcom military mobile satellite system for Navy, Ground and Air Forces. However, the first real global MSC system was the US Marisat military satellite network, which employed SES and L-band antenna systems similar to ceased Inmarsat-A and B satellite terminals. The new generations of Inmarsat Inmarsat-FB (FleetBroadband), Fleet One and Global Xpress Shipborne Antennas are illustrated in **Figure 4.**

1. Inmarsat-FB MSA – The FleetBroadband (FB) was launched by Inmarsat sometimes in 2007 providing high-speed Internet connectivity, crew IP solutions in parallel with E-mail, Web, data, Virtual Private Network (VPN) and voice calling at sea. It enables tracking and telemetry functionality, so shippers on shore have all the information they need about voyage, Estimated Time of Arrival (ETA), cargo operations, real-time engine data for maintenance, drilling data for improving production or position data for fleet tracking and management and

so on. There are two satellite terminal types defined and type-approved for the FB maritime service utilizing Inmarsat-4 satellite constellation at L-band, referred to as Class 8 (High Gain Antenna "FB500") and Class 9 (Low Gain Antenna "FB250" and "FB 150") satellite terminals. The key difference between Class 8 and Class 9 is the antenna. Therefore, for each type of FB terminal Inmarsat defines:

1. The air interface at the output of the terminal's antenna;
2. The mandatory features and service types for each class of user terminal; and
3. The performance requirements of the user terminal.

The Sailor 500 FB transceiver uses the TT-3052A antenna, which is a maritime Broadband Global Area Network (BGAN) antenna that complies with Inmarsat's Class 8 definition for ship antenna shown in **Figure 4 (Left).** This antenna is larger and provides more bandwidth than the TT-3050A used for the Sailor 250 FB system.

This antenna contains all functions for satellite tracking including a GPS system. A single coaxial cable carries all RF communication, supply voltage and modem connection between the antenna and the terminal. Manufacturers must meet all of these requirements in order to obtain Type Approval antennas. The definition of other equipment features such as physical connections, user interfaces, firewalling, routing control etc is determined by each manufacturer according to specific market-driven needs. Because of the possibility of different physical interfaces on terminals from different antenna manufacturers users should pay particular attention to the installation guidelines for different terminal configurations and features.

2. Inmarsat-GX MSA – The Global Xpress (GX) is the newest Inmarsat standard that is using the last constellation of Inmarsat-5 satellites at Ka-band RF, which Cobham Sailor 100 GX satellite reflector antenna with radome is illustrated in **Figure 4 (Middle).** This light and compact light and compact antenna is an advanced 3-axis stabilized tracking system designed for the Inmarsat GX satellite network. It is a direct development from the immensely successful SAILOR 900 VSAT antenna systems, which have created a new industry standard through innovative design and reliable operation. The GX antenna features advanced Tracking Receiver technology that enables it to verify the right satellite in less than a second. It uses a single cable between satellite antenna known as Above Deck Equipment (ADE) and transceiver with peripherals known as Below Deck Equipment (BDE) for RF, power and data, while advanced features such as Automatic Azimuth Calibration and Automatic Cable Calibration significantly reduce installation time further.

Figure 5: Land Vehicular VSAT Road and Rail Antennas and TVRO Vehicle borne Antenna.

Source: Author.

This GX antenna provides reliable access to the full range of high throughput satellite broadband services for maritime business applications, ships operations and crew welfare, including passenger multimedia services. The technical specifications of ADE are as follows: Antenna pedestal is 3-axis stabilized tracking with integrated GPS Rx; Antenna reflector system is reflector/sub-reflector including ring focus; Transmit Gain is 47.5 dBi at 29.5 GHz (excl. radome); Receive Gain is 44.0 dBi at 19.7 GHz (excl. radome); System G/T is 20.1 dB/K at 19.7 GHz, at ≥10° elevation (ε) and clear sky (incl. radome); Block Up Converter (BUC) has output power is 5 W GX BUC; EIRP ≥53.5 dBW (incl. radome) is MAX. 36.0 dBW/40KHz; Low Noise Block (LNB) GX Ka is single band LNB; Tracking Receiver Internal is "all band/modulation type" including e.g. power, DVB-S2, GSC and modem RSSI; Polarization is Circular Cross-Pol (Inmarsat GX, TX: RHCP, RX: LHCP); Elevation Range is -25° to +125°; Azimuth Range is Unlimited (Rotary Joint); Ship motion (angular) is Roll +/-30°, Pitch +/-15°, Yaw +/-10°; Ship, turning rate and acceleration is 15°/S2 and 15°/S2; ADE motion is linear accelerations +/-2.5 g max any direction; Satellite acquisition is automatic with or without Gyro/GPS Compass input; Humidity tolerance is 100%; Rain/IP class considers EN60945 Exposed / IPX6; Wind tolerance is about 80 kt for operational and 110 kt for survival conditions; Ice survival tolerance is 25 mm/1"; Solar radiation is 1120 W/m2 to MIL-STD-810F 505.4; Compass safe distance is 1 m/40" to EN60945; Dimensions (over all) Height: H 150 cm/58.9" - Diameter: Ø 130 cm / 51.3" and Weight is 126 Kg/ 276 lbs.

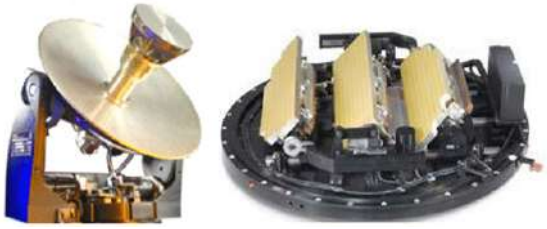
3. TVRO Antenna – Inmarsat GEO satellite operator provides stabilized ships antennas that deliver high-quality TV reception or TV Receive-Only (TVRO) systems suitable for any region of the world. This TV antenna can be installed onboard any type and size of merchant ships, sea rigs or platforms, fishing boats and luxury cruise vessels, which are designed to withstand the harshest marine conditions and to continue working in even the heaviest seas on the globe. Inmarsat has designed four types of shipborne stabilized TVRO antenna, such as metricconverterProductID0.6 metres0.6 metres ST 24 model, 1.2 metres 5004 model, 1.25 metres t130W in 66.5" radome and 1.5 metres 6004 in 76" radome. The last 6004 type of TV antenna is illustrated in **Figure 4 (Right),** which total weight is approximately 159 kg and DAC 2202 is a control unit.

7. Designs of Antennas for LMSC.

The vehicleborne satellite antenna system for LMSC provides communications, broadband and TVRO transmission of multimedia information such as audio and video images, voice and data by the integration of satellite communication, microwave-band transmission, wireless LAN, Internet, mobile public network as well as audio and video compression. These antennas are serving road vehicles and rail wagons with Satcom On-The-Move (SOTM) systems via Inmarsat and other GEO satellite constellations. However, the special vehicleborne satellite antenna system can quickly establish satellite broadband and TV transmissions

1. KVH Land Vehicular mini-VSAT Antenna - The TracPhone V3-IP radome antenna units of KVH producer are mini-VSAT Broadband communications system for road vehicles on the move shown in **Figure 5 (Left).** This antenna delivers a seamless and consistent Internet access with antennas that are smaller and lighter than traditional VSAT antennas. These VSAT systems consist of an antenna and Integrated CommBox Modem (ICM) that connect to a land-based hub via a Ku-band GEO satellite constellation. The ground Hub is managed by a Network Operations Center (NOC) then provides the link to the Internet and the terrestrial telephone network.

Figure 6: VSAT and TVRO Airborne Antennas.



Source: Author.

The antenna transmits RF energy that is potentially harmful. Whenever the system is in use it is necessary to make sure everyone stays more than 11 m (36 feet) away from the radome antenna. However, no hazard exists directly below the antenna. Both antennas may accept an external GPS input as a backup to the antenna's internal GPS. In this sense, it will be more secure to connect a backup GPS and prevent a loss of service if the antenna's internal GPS fails. The specifications of this antenna are: Service Coverage Areas are Seamless Worldwide; RX receive/TX transmit RF band is 11.7-12.75 GHz/14.0-14.5 GHz; Antenna gain is 31.0 dBi (RX-band, min); Transmit power (BUC) 3 W max for V3-IP; Elevation range is 7.5° to 75°; Azimuth range is 720° rotation max; Maximum Download Speed is about 2 Mb/s and Maximum Upload Speed is 128 Kb/s; Antenna Dish Diameter is 36.8 cm (14.5"); Antenna Diameter x Height/Weight is 9.4 cm (D) x 44.7 cm (h)/11.3 kg (15.5" (D) x 17.6" (h)/ 25 lbs).

2. Orbit Rail Low-profile VSAT Antenna – The Orbit RailTRx antennas are supporting a variety of stabilized train antenna system configurations in Ku and Ka-bands. As a common platform, it is designed to accommodate the current and future needs of the train market. As such, these elliptic antennas are an optimal solution for the evolving rail satellite broadband communications needs of inter-city, regional and high-speed trains. The RailTRx antenna product line comprises series of RailTRx 2-300 features a low profile high gain Ku-band antenna, shown in **Figure 5 (Middle)**. The values of 2-300 antennas are: RF Ku-band for Tx is 13.75 to 14.50 and for Rx is 10,95 to 12.75 GHz; G/T is 13.5 dB/K^o; EIRP 44 dBW; Travel Azimuth is 360^o; Elevation is +5 to +50; Antenna diameter is105.8 cm (41.6 in); Height is 48.8 cm (19.2 in); and Weight is 96 kg (211 lbs).

3. KVH Vehicular TVRO Antenna – The KVH manufacturer of vehicular TV antennas for road and rail applications has designed TracVision RV1 radome antenna shown in **Figure 5 (Right).** This satellite antenna is High Definition TV (HDTV) compatible, DVB-S2 acquisition and provides excellent performance and reliability for passengers in family cars, buses and rail wagons with hundreds of channels of satellite TV entertainment in no time. In addition, high performance TV antenna tracking with advanced algorithms provides crystal-clear television picture in extreme conditions. Antenna Unit Diameter x Height & Weight for RV1 are 34.3 cm x 33.7 cm (13.5" x 13.3") & 3.6 kg (8 lbs); and for A9 are 81 cm x 12.7 cm (32" x 5") & 22.5 kg (49.5 lbs).

8. Designs of Antennas for AMSC.

The DVB-RCS VSAT satellite technology is developed more than three decades ago and is taking big role in MSC systems and for Satellite Aeronauticak Broadband (SAB) applications. This service is providing broadcast, broadband, multimedia and very fast Internet with IPTV via GEO satellites using different antenna solutions. The antenna serves just for transceiving facilities or can be integrated with IPTV reception. In general, the new VSAT broadcasting service provides digital Voice, Dataq and Video over IP (VDVoIP). There is also possibility to install onboard aircraft just antenna for receiving TV (TVRO) transmissions.

1. VSAT Ku-band AL-1614 Tx/Rx Antenna – This avionics DVB-RCS Tx/Rx antenna based upon a proven concept implemented on various applications of Orbit Technology Group is used over the last 15 years, which antenna without radome is illustrated in **Figure 6 (Left)**.

This antenna is based on modular sub-assemblies such as follows: ACE, Gear/Motor/Encoder Assembly and RF Front End, which are designed, tested and proven to meet all necessary airborne environmental conditions. It provides access to satellite broadband networks anywhere, anytime under any weather condition while passengers are in the air, and has become essential. It is one of the first innovative stabilized VSAT Ku-band antenna solutions. Comprising a compact yet efficient dual reflector antenna with an RF front end delivering optimal nonstop quality connectivity with the selected satellite. The components of this antenna are assembled and integrated for this specific application in order to meet the required compact system design of Airborne Ku-band AL-1614 Tx/Rx Antenna. The antenna unit complies with ARINC, ETSI and FCC satellite regulations and provides the following key benefits and features: it is efficient "Dual Reflector" of antenna system, high EIRP of > 44 dBW, G/T is >9.5dB/°K and the minimum dynamic tracking error meets aeronautic standard RTCA 160D, provides the typical data rate of 3 Mb/s in reception and 512 KB/s in transmission, typical Eb/No is 6dB and RF bands of antenna are for Tx 14.00 - 14.50 GHz and for Rx 10.95 to 12.75 GHz.

4. Breakthrough Receiving Broadband Antenna for ASB – The P&L International Inc. designed the next generation of airborne ASB Antenna Systems known as ZipPhaser-Air aviation antenna for all size aircraft broadband capability onboard

commercial airlines that need capability to connect over the Ocean Regions, which is illustrated in **Figure 6 (Right)**. This antenna system being proposed offers the highest technology phase array capability for DSB TV broadcasting onboard entertainment applications. The antenna system would install on the aircraft with a small low profile footprint and radome with and astounding low weight. The modem router uses an iDirect X5 Evolution and the antenna controller is included. The infrastructure on the aircraft can be wired or WiFi wireless the choice is the of the airlines operator. The X5 router and HUB provide automatic antenna beam switching capability as the aircraft moves from one region to the next providing seamless transition for transatlantic flights. The TV broadcasting network Ground Stations are located in placecountry-regionItaly, placeStateFlorida, placecountry-regionSingapore and placeStateHawaii. Moreover, the broadcasting satellite network is made up of a combination of Intelsat and Telesat Ku-band satellite transponders that downlink to the teleports infrastructures. Installation of this antenna would be simple with minimum effects to the aircraft. Today instant and uniterrupted airborne communications is a must globaly employing the breakthrough technology. However, the ZipPhaser-Air aviation antenna systems is the only low profile, 2-way Ku-band antenna system for all type of aircraft. Based on a unique flat panel technology, this antenna system has been especially designed to meet airlines expectation to provide reliable connectivity and global coverage at unprecedented speed and quality.

Conclusions

The design and configuration of MSA needs to be compact and lightweight especially for LMSC systems. On the other hand, the physical characteristics for MMSC and AMSC applications may be quite different, but both have to be designed compact for harsh environments and very extreme operating temperatures. These requirements will be difficult to achieve because the compact antenna has two major electrical disadvantages such as low gain and wide beam coverage, and because directional antenna has very heavy components for satellite tracking and getting satellite in the focus. However, a new generation of powerful satellites with high EIRP and G/T performances should permit the design of compact and lightweight MSA platforms.

In such a way new physical shapes and less weight are very important requirements in connection with compactness and lightweight, what will permit easier installation and maintenance. Shipborne antennas still have very big dimension especially those integrated in Inmarsat Standard FB and new Global Xpress. The new Inmarsat antenna for FleetBroadband is getting smaller dimension and can be employed for communication s and multimedia transmissions. The Swift64 airborne antenna is well suited for large jumbo jets, which installation requirements are not as limited compared to very small aircraft and helicopters. On the other hand, new aeronautical Swift-Broadband can be installed even on small jets with reduced space on fuselage. However, a phased array MSA is considered to be the best prototype for large aircraft and helicopters because of its very low profile, convenient mechanical strength and easy installation.

References.

[1] Evans B.G., “Satellite Communication Systems”, IEE, London, 1991.

[2] Fujimoto K. & James J.R. “Mobile Antenna Systems Handbook”, Artech House, Boston, 1994.

[3] Gallagher B. “Never Beyond Reach”, Book, Inmarsat, London, 1989.

[4] Group of Authors, “Antenna Design”, Peter Peregrinus, London, 1986.

[5] Canadian Marconi, “CMA-2102 Aero Satcom High-Gain Antenna”, Canadian Marconi, Ville St-Laurent, 1997

[6] Imarsat, “Inmarsat Aeronautical Services Reference Manual”, Inmarsat, London, 1995.

[7] Huurdeman A.A., “Guide to Telecommunications Transmission Systems”, Artech House, Boston-London, 1997.

[8] Ilcev D. S. “Global placeMobile Satellite Communications for Maritime, Land and Aeronautical Applications”, Theory Volune 1 & Applications, Volume 2, Springer, Boston, 2016 / 2017.

[9] Law P.E., “Shipboard antennas”, Artech House, Washington, 1983.

[10] Maral G. at al, “Satellite Communications Systems”, John Wiley, Chichester, 1994.

[11] Ohmory S., Wakana. H & Kawase S. “Mobile Satellite Communications”, Artech House, Boston, 1998.

[12] Cobham, “Sailor 500 FB Transceiver TT-3052A Antenna”, Cobham SATCOM Maritime, Lyngby, Denmark, 2020.

13] Inmarsat, “Inmarsat-GX Global Xpress Antenna System”, Inmarsat Inc, London, 2015,

[14] KVH, “KVH Land Vehicular mini-VSAT Antenna”, KVH Industries, Middlletown, US, 2017.

[15] Orbit, “Orbit Rail Low-profile VSAT Antenna”, Orbit Communication Systems Ltd. Netanya, Israel, 22010.

[16] KVH, “KVH Vehicular TVRO Antenna”, KVH Industries, Middlletown, US, 2022.

[17] KVH, “VSAT Ku-band AL-1614 Tx/Rx Antenna”, KVH Industries, Middlletown, US, 2012.

[18] P&L International, “Aircraft TVRO Solutions”, Weddington, NC, 2015.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 19–25

ISSN: 1697-4840, www.jmr.unican.es

Onboard Lifestyle Of Seafarers: Their Experiences

Manilyn Abucay[1,*]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 24 Jun 2023;
accepted 16 Jul 2023.

Keywords:
seafarers, lifestyle, health, design.

ABSTRACT

This research investigation was carried out to determine seafarers' onboard lifestyle to maintain their health and well-being at sea and ashore.
The researcher employed the blended method study, a quantitative and qualitative research design, as it is the most appropriate technique. The study was conducted at Danao City port. The research respondents of the study were 30 seafarers. Descriptive statistical tools to answer the specific question were used. The input of the study was the data gathered from the questionnaire and was statistically treated.
This study's salient findings are that most seafarers are young and value harmonious relationships with others to have a healthy and peaceful work environment. This study concluded that the onboard lifestyle of seafarers in terms of mental, spiritual, and physical aspects is very beneficial and can prevent the mental health issues that can arise due to a persistent physical condition. In general, seafarers have a strong faith in God and learn how to manage the challenges encountered, which can help them have clearer thinking and good condition while working onboard a ship. Also, good health and well-being seminars for every seafarer onboard are now recommended. .

1. Introduction.

Seafaring is a profession that demands more than most others. It can play havoc with the mind, body, and soul. Being far from home, away from people they care about, and dealing with a demanding job under challenging circumstances can take its toll.

There was a time when a seafarer could be evasive about the truth. They may only disclose past medical conditions during their pre-employment medical check if they are willing to be accepted. Seafarers, particularly those with experience, are in high demand. As a result, medical care companies are developing solutions that benefit seafarers concerned about sustaining their families and ship management concerned about their operations' safety.

A recent study based on registry data from several Northern European countries found seafaring among the occupations with the highest standardized incidence rates for all cancers combined, which might be due to various factors, among them exposure to chemicals as well as sunlight but also lifestyle behaviors, such as smoking, alcohol consumption, and diet (Pukkala *et al*., 2009; Oldenburg *et al*., 2010).

To lessen the danger of acquiring various diseases and types of work that seafarers encounter onboard, seafarers must solve their mental and physical health problems. When considering the health and lifestyle of seafarers, keep the following factors in mind: unpredictable job schedules and long working hours due to operational needs, the little community to which one must adapt and work, the feeling of being away from home, and the complicated working environment, as well as all the hazards that come with it, local medical facilities and finite medical supplies, the confined nature of life onboard ship, and the climate (Kairis, 2012).

The study adds to our understanding that health promotion is a unique but vital workplace for many trade-dependent economies independent of the maritime industry. Because the workplace creates many conditions that promote or reinforce unhealthy behavior, it also serves as an essential arena for sea-

[1]Cebu Technological University, Filipinas.
[*]Corresponding author: Manilyn Abucay. E-mail Address: manilyn.abucay@ctu.edu.ph.

farers' mental, physical, and spiritual well-being.

The goal of the study was to encourage sailors to take care of their health and well-being by focusing on spiritual aspects, such as maintaining a peaceful and harmonious relationship with others, physical elements, such as staying healthy and fit at work, and mental factors such as how to deal with problems encountered while onboard.

2. Research Methodology.

Discusses the methods used to gather relevant data from the respondents. These include the research design, environment, respondents, instrument data sources, data gathering procedures, and statistical data treatment. It has used different methods for the quantitative and qualitative approaches, as both encompass distinct purposes to serve. Besides, the strategies implemented to enhance the validity and reliability of the studies are also explained in detail.

2.1. Research Design.

This study determines the seafarer's occupational profile's influence on their lifestyle onboard. The researcher employed this blended method study, a quantitative and qualitative research design, as it is the most appropriate technique.

The descriptive method describes the data and characteristics of what is being studied. It is based on a small set of individuals, often only one person or a single small group. The researcher was able to determine the level of the lifestyle of the seafarers on board. Narrative inquiry is a form of qualitative research in which the stories themselves become the raw data. This approach has been used in many disciplines to learn more about the culture, historical experiences, identity, and lifestyle.

2.2. Research Environment.

The study was conducted at Danao Port of Danao City, Cebu. Danao Seaport is an inter-island passenger and vehicle transportation port (RoRo). It serves the City of Danao and its surrounding area. It is located in the city, just 700 meters distance from the center of the town, or approximately 4 minutes, with light traffic. The research locale was selected due to the accessibility of the respondents and the researcher.

2.3. Research Respondents.

Purposive sampling was used in this study. This non - probability sampling is in which researchers rely on their judgment when choosing the population to participate in this study. It is composed of survey and one on one interview approaches.

The research respondent of the study were seafarers at the port of Danao City, Cebu. The respondent must be a seafarer. This study comprises 30 selected seafarers at Danao Port of Danao City, Cebu.

Table 1: Distribution of the Respondents.

RESPONDENTS	FREQUENCY	%
Males	30	100%
Females	0	0%
Total	30	100%

Source: Author.

2.4. Research Instruments.

The researcher used a survey questionnaire as its research instrument. The questionnaire was composed of three major parts. The first part dealt with the personal profile of the respondents in terms of age, gender, number of years onboard, licensed and civil status; the second part dealt with the onboard lifestyle of the respondents in terms of mental/social, spiritual, and physical aspect; and the third part, dealt with challenges they encountered onboard the vessel. The questionnaire is composed of 4 interview questions and 15 questions: 5 of the spiritual aspect, 5 of the mental elements, and 5 of the physical aspect.

2.5. Research Procedures.

2.5.1. Gathering of Data.

The data relevant to the study was through primary source using survey questionnaire that was distributed directly to the respondents and aided with personal interview for some issues not clear. Secondary data was taken from books & internet.

2.5.2. Treatment of Data.

The following statistical tools were used in the study.

Frequency Count and Per Cent were used to summarize, analyze and interpret the profile of the respondents.

Weighted Mean was used to summarize, analyze, and interpret the responses on the lifestyle of the seafarers in terms of the mental aspect, spiritual aspect, and physical aspect;

Chi-square and Pearson Coefficient C were used to determine the significance and strength of the relationship between the respondents' profile and lifestyles as seafarers on-board.

3. Presentation, analysis and interpretation of data.

This chapter deals with the presentation, analysis, and interpretation of data gathered from the respondents of this study.

3.1. Profile of the Respondents.

This section presents the profile of the respondents in terms of age, gender, civil status, current position, and position. Table 2 summarized the results.

As indicated in table 1, a majority of the respondents are 20 – 24 years old (36.67%), all-male (100%), primarily single (70%), current position is on operational level (53.33%), and mostly deck cadet (33.33%). Furthermore, most of the respondents are on board for less than one year (46.67%) and (76.67%) have professional license that is not applicable. These

Table 2: Profile of the Respondents.

Profile	Frequency	Per Cent
Age (years)		
• 20 - 24	11	36.67
• 25 - 29	8	26.67
• 30 - 34	5	16.67
• 35 & above	6	20.00
Gender		
• Male	30	100.00
• Female	0	0.00
Civil Status		
• Married	9	30.00
• Single	21	70.00
Current Position		
• Management Level	6	20.00
• Operational Level	16	53.33
• Support Level	8	26.67
Position		
• 2nd Engineer	1	3.33
• AB	4	13.33
• Chief Engineer	3	10.00
• Chief Mate	1	3.33
• Deck Cadet	10	33.33
• Engine Cadet	4	13.33
• Master	2	6.67
• Oiler	4	13.33
• Steward	1	3.33
Number of Years On-board		
• Less than 1 year	14	46.67
• 1 to 5 years	7	23.33
• 6 to 10 years	4	13.33
• 11 years & above	5	16.67
License		
• Master Mariner	1	3.33
• Officer in Charge Engine Watch	4	13.33
• Officer in Charge Deck Watch	2	6.67
• License Not Applicable	23	76.67

Source: Author.

findings imply that most seafarers are young because they provide shipboard training programs that allow all cadets to learn the sea-going laboratory, wherein they are required to complete their **training** record books. This must come as no surprise that anyone seeking a career in seafarer jobs must have a strong work ethic, tenacity, punctuality, people skills, courage, and diligence. These are all highly desirable qualities in many industries, but in maritime jobs, they are practically required. With the guidance of the management and support level, the deck and engine **cadet** assist in the day-to-day operations and maintenance of the ship. They help with preparations before departure, navigation, safety and maintenance **duties,** and cargo-related issues. Deck and engine **cadets** are found on just about every type of seafaring vessel.

A recent study showed that it is common for Filipino seafarers to work on board under temporary contractual arrangements between 6 and 12 months, with 8 to 12-hour work days. Watch-keeping deck officers work seven days a week, on a 'week in and week out' basis. Seafarers in other positions may have an occasional Sunday off when their vessel is not in port. Reduced opportunities for shore leave make the ship even more confined in a risky and uncomfortable environment. Accounts of how Filipino seafarers grapple with these contemporary realities can provide insight into their day-to-day lives (Acejo I., 2021).

3.2. Lifestyle of the Respondents.

This section presents the lifestyle of the respondents in terms of mental, spiritual, and physical aspects. Table 3 shows the mental aspect.

Table 3: Lifestyle of the Respondents in Terms of Mental Aspect.

Indicators	Mean	Description	Interpretation
1. Allowing self to be happy even there's lot of problem outside.	3.37	**Always**	Very Healthy Lifestyle
2. Doing things that can help our brain to relax like listening to music, drawing, playing guitar and etc.	3.63	**Always**	Very Healthy Lifestyle
3. Have a good condition while working on board ship.	3.90	**Always**	Very Healthy Lifestyle
4. Have time to communicate families and love ones when have free time.	3.80	**Always**	Very Healthy Lifestyle
5. Have enough time for sleeping at least 8 hours a day.	3.10	**Oftentimes**	Fairly Healthy Lifestyle
Overall Mean	*3.56*	***Always***	*Very Healthy Lifestyle*

Source: Author.

As shown above, the overall mean of the mental aspect of the respondents is 3.56 and described as ***always***, which means that the respondents had *very healthy lifestyle* as seafarers onboard. The top one indicator on this aspect is having *a good condition while working onboard ship* which has a mean of 3.90 and described as ***always*** which mean that the respondents had a *very healthy lifestyle* as seafarers onboard. Furthermore, the top two indicators for this aspect are having *time to communicate with families and loved ones when having free time* with a mean of 3.80 and described as ***always*** and interpreted as a very healthy lifestyle. However, the indicator *has enough time for sleeping at least 8 hours a day* got, a mean of 3.10 and described as ***frequently***, which means *a fairly healthy lifestyle.* These findings imply that most of the seafarers are showing compassion to work and even there is a lot of problems outside, they can manage to be happy and relax during free time and spend time communicating their families and loved ones to motivate job performance.

Seafaring is still associated with relevant mental health risks. Information on known stress factors on board should be provided to seafarers to help them lower stress perception. Strategies for coping with inevitable stress conditions should also be investigated and developed. Strategies to decrease stress risks should be directed to the different categories of seafarers, and the results of specific interventions should be evaluated (Carotenuto A. et al., 2012).

Strategies to support good mental health need to be orientated towards proactive shipboard improvements designed to stimulate positive social interaction with those on board and those on shore, as well as to provide opportunities for sailors to relax, refuel, and elevate their spirits. Improvements in terms and conditions in support of a good work-life balance for seafarers are also required (Sampson and Ellis, 2019).

This section shows the lifestyle of the respondents in terms of spiritual aspect.

Table 4: Lifestyle of the Respondents in Terms of Spiritual Aspect.

Indicators	Mean	Description	Interpretation
1. Attending holy mass.	2.20	**Sometimes**	Less Healthy Lifestyle
2. Reading the bible/pray during free time.	2.37	**Sometimes**	Less Healthy Lifestyle
3. Engagement with religious community members.	2.53	**Oftentimes**	Fairly Healthy Lifestyle
4. Maintaining harmonious relationship with others onboard.	3.87	**Always**	Very Healthy Lifestyle
5. Believing and have faith in God during the hard times.	3.97	**Always**	Very Healthy Lifestyle
Overall Mean	*2.99*	***Oftentimes***	*Fairly Healthy Lifestyle*

Source: Author.

On the spiritual aspect, the overall mean is 2.99 and described as ***oftentimes,*** which means that the respondents have *a fairly healthy lifestyle* on board. The top indicator in this aspect is the one about *believing and having faith in God during the hard times* with a mean of 3.97 and described as ***always*****,** which means that the respondents have *a very healthy lifestyle*. The top two indicators in this aspect are *maintaining a harmonious relationship with others onboard* with a mean of 3.87 and described as ***always***, which means that the respondent has *a very healthy lifestyle*. However, two indicators were less rated by the respondents, namely: *reading the bible/pray during free time* and *attending holy mass,* which were both described as ***sometimes*** and interpreted as *a less healthy lifestyle*. These findings imply that seafarers showed strong faith in God even they seldom attend the mass regularly due to the hectic schedule of their stay in port. Also, seafarers valued harmonious relationships with others to have a healthy and peaceful work environment.

However, despite the importance of faith to many seafarers, there appeared to be no appetite for increased religiosity at sea. On the contrary, seafarers took great care to ensure that religion and faith remained largely private on-board while being concerned not to prohibit a limited public expression of faith entirely. There seemed to be a consensus that religion should not interfere with work practices, and where, on rare occasions, it was allowed to do so, it produced a degree of antipathy. This seems to confirm observations that where provision for faith-based needs at work involves inconvenience to colleagues, it can produce resentment (Sampson et al., 2020).

This section shows the lifestyle of the respondents in terms of physical aspect.

Table 5: Lifestyle of the Respondents in Terms of Physical Aspect.

Indicators	Mean	Description	Interpretation
1. Engage in sports like basketball or something that can improve physical health onboard.	3.17	**Oftentimes**	Fairly Healthy Lifestyle
2. Eating nutritious foods every day.	3.20	**Oftentimes**	Fairly Healthy Lifestyle
3. Maintaining exercise every day.	2.93	**Oftentimes**	Fairly Healthy Lifestyle
4. Drink plenty of water at least 8-10 glass a day.	3.90	**Always**	Very Healthy Lifestyle
5. Maintaining individual's hygiene.	3.87	**Always**	Very Healthy Lifestyle
Overall Mean	*3.41*	***Always***	*Very Healthy Lifestyle*

Source: Author.

On the physical aspect, the overall mean is 3.41 and described as ***always*** which means that the respondents have *a very healthy lifestyle* in this aspect. The top one indicator in this aspect is on *drinking plenty of water at least 8-10 glasses a day* with a mean of 3.90, described as ***always*****,** and interpreted as *a very healthy lifestyle*. The top two indicators in this aspect are on *maintaining an individual's hygiene* with a mean of 3.87, described as ***always***, and interpreted as *a very healthy lifestyle*. Meanwhile, the least rated indicator on this aspect is on *maintaining exercise every day* with a mean of 2.93, described as ***oftentimes***, and interpreted as *a fairly healthy lifestyle*. These findings imply that seafarers showing great care of their physical health by staying hydrated every day, most of them are exposed to the hot weather while working onboard the ship, drinking enough water will help their body to stay healthy and fit at work. Also, seafarers are particular to their health hygiene to eliminate the spread of the virus, bacteria, and other illnesses and the risk of medical conditions that can cause a problem at work.

Seafaring is a highly physically demanding profession in a risky environment. Seafarers face challenging working conditions when they are on board. Working far from home for several months can lead to difficulties for their overall health. Their safety and health status are at risk of various factors such as exposure to chemicals and sunlight as well as lifestyle behavior such as diet and smoking, so mentioned subjects are a significant concern for companies and themselves. In comparison to jobs ashore, seafarers are exposed to physical and psychosocial stressors and some specific mental problems. Also, hospitalization and mortality rates among seafarers are higher than their age-matched peers due to exposure to job-specific health-related risk factors. Being far from home for an extended period, long working hours, heavy workloads, accidents, maritime disasters, communicable diseases, and pirate incidents are some of the main stressors, risks, and challenges of seafarers on board ships that can cause some consequences for their physical and mental health (Baygi et al., 2018).

In addition, good health has become an important safety factor: good health is crucial to preventing strain injuries and ensuring alertness and optimal performance at work. Physical activity is a powerful preventive medicine for maintaining good health and preventing overweight and musculoskeletal disorders (Geving et al., 2007).

3.3. Relationship between the Respondents? Profile and Lifestyle.

This section presents the result of the test of hypothesis concerning the relationship between the respondents' profile and their lifestyle as seafarer on-board. Table 6 summarized the results.

Table 6: Relationship between the Respondents? Profile and Lifestyle.

Variables	df	Computed Value	Critical Value	Decision on Ho	Interpretation
Age in relation to:					
Mental Aspect	3	1.418	7.815	Failed to Reject Ho	Not Significant
Spiritual Aspect	6	6.277	12.592	Failed to Reject Ho	Not Significant
Physical Aspect	3	2.268	7.815	Failed to Reject Ho	Not Significant
Gender in relation to:					
Mental Aspect Spiritual Aspect Physical Aspect	Cannot be performed; the respondents are all male; hence cross-tabulation to perform Chi-square is not possible				
Civil Status in relation to:					
Mental Aspect	1	0.286	3.841	Failed to Reject Ho	Not Significant
Spiritual Aspect	2	3.214	5.991	Failed to Reject Ho	Not Significant
Physical Aspect	1	2.066	3.841	Failed to Reject Ho	Not Significant
Current Position					
Mental Aspect	2	8.850	5.991	Reject Ho	Significant (C=0.48; Moderate)
Spiritual Aspect	4	3.490	9.488	Failed to Reject Ho	Not Significant
Physical Aspect	2	1.373	5.991	Failed to Reject Ho	Not Significant
Position					
Mental Aspect	8	9.120	15.507	Failed to Reject Ho	Not Significant
Spiritual Aspect	16	19.479	26.296	Failed to Reject Ho	Not Significant
Physical Aspect	8	5.625	15.507	Failed to Reject Ho	Not Significant
Number of Years On-board					
Mental Aspect	3	5.211	7.815	Failed to Reject Ho	Not Significant
Spiritual Aspect	6	5.259	12.592	Failed to Reject Ho	Not Significant
Physical Aspect	3	7.959	7.815	Reject Ho	Significant (C=0.46; Moderate)
License					
Mental Aspect	3	1.826	7.815	Failed to Reject Ho	Not Significant
Spiritual Aspect	6	7.269	12.592	Failed to Reject Ho	Not Significant
Physical Aspect	3	1.919	7.815	Failed to Reject Ho	Not Significant

Source: Author.

As shown in Table 6, all paired variables have no significant results except for *the current position* and *mental* aspect of the seafarers' lifestyle and the *number of year's on-board* and *physical aspect* of the seafarers' lifestyle. For the current position and mental aspect, the computed value (8.850) for the paired variables is greater than the critical value (5.991) at a 0.05 level of significance. For the number of year's on-board and physical aspect, the computed value (7.959) for the paired variables is greater than the critical value (7.815) at a 0.05 level of significance. The said results led to the rejection of the null hypotheses. It means that there is a significant relationship between the current position and the mental aspect lifestyle of the respondents. Based on the Pearson coefficient C (0.48) generated from the computed value, the strength of the relationship between the current position and mental aspect lifestyle is described as *moderate*. Likewise, there is a significant relationship between the respondents' number of years on-board and physical aspect lifestyle. Based on the Pearson coefficient C (0.46) generated from the computed value, there is a moderate relationship between the number of years on-board and the physical aspect lifestyle of the respondents.

These findings imply that being a seafarer is not an easy job, the higher position they have the harder responsibility they take. Management level is responsible for the safety of the crew, cargoes, and vessel and they are the command of the ship. A support level is responsible for performing assigned tasks, duties, and responsibilities on board sea-going ship under the direction of an individual serving at the operational and management level.

Seafarers are often exposed to psycho physical stress due to isolation, separation from family, time pressure, and long working days. In addition, noise from ship operations, vibration from the engine, and weather-related ship motion are other significant stressors that can reduce sleep quality on board. Some of the ship's personnel (particularly the nautical officers and watch keeping crew deck ranks) work 24-h shifts. Sleep patterns are disrupted as a result of these alternating day/night shifts. Shift systems, such as the 6:6 and 4:8 shift systems, only allow for brief interruptions in work for rest and recovery. In the 6:6 system, a watch keeper works for six hours and then has six hours of free time, which is rotated with the second watch-keeper. Typically, shift changes occur at 6:00 a.m., 12:00 p.m., 6:00 p.m., and midnight. Three nautical officers take turns working four hours each, followed by an eight-hour rest period, under the 4:8 system. At 4:00 a.m., 8:00 a.m., 12:00 p.m., 4:00 p.m., 8:00 p.m., and midnight, shifts change. Increased sleepiness and shorter sleep, particularly during night work of the 6:6 system (midnight to 6 a.m.) Oldenburg et al. (2009).

Aside from the fact that seafaring is still dominated by a male lifestyle culture, which may explain the comparatively high smoking rates and unhealthy, high-fat eating habits, one of the main reasons for such differences may be found in the specific environmental conditions encountered by seafarers. Onboard periods are frequently lengthy, and leisure time activities are typically limited. Meals, snacking, resting, and corresponding with family/friends consume the majority of leisure time, while only a minority of employees engage in physical fitness activities. The confined space on board makes the most popular form of exercise for people on shore, running/walking, impossible, and the constant change between longer periods on board and longer periods at home may make it difficult to establish important routines (Hjarnoe & Leppin, 2013).

In the study of Iversen (2012), it is commonly stated that seafaring is a hazardous occupation. The International Maritime Health Association (IMHA) says it best, it has been established that seafaring is one of the most physically demanding professions in one of the most dangerous work environments: the sea. Numerous studies and reports on seafarers physical and mental health, illnesses, and causes of death attest to this assertion.

3.4. Challenges and Problems Encountered.

This section presents the challenges and problems and how they solve these challenges encountered by the respondents. These presents eight common themes derived from one-on-one interview; 1 session were held for 5 minutes per informants; interview was audiotaped and transcribed; validation of information was done together with the informants. After data saturation was reached, data analysis began.

4. Developing of emergent themes.

1. The challenges of seafarers onboard are the bad weather during loading of cargoes and maneuvering.	Bad Weather during loading of cargoes and maneuvering.	Ship navigation
2. The Greatest Challenges of seafarers onboard is the difficult job during engine failure.	Engine Failure	
3. The Seafarers always apply minimum Safety Standards to ensure the safety of the crew, passengers, cargoes and the vessel.	Apply Safety standard	
4. Being far from family or home sickness	Home sickness	Seafarer's strong family ties.
5. The Greatest Challenges of seafarers onboard are Miscommunication of passengers and misunderstanding of crewmates that creates conflict. Good Communication to the passengers and has time to communicate with the family is important.	Misunderstanding of crew and passenger.	Seafarer's Good attitude is important.
6. The Seafarers deal with challenges onboard by being positive in all aspects, flexible, family motivation, hardworking, God fearing, focus the work and be respectful all the time.	Being Positive in all aspect.	
7. The Common problem of seafarers onboard is financial problem	Financial Problem	Financial
8. The Seafarers deal with problems onboard is by spiritual beliefs, they believe in God and pray during hard times and trusting God to dock safely.	Strong Spiritual beliefs	Seafarer's strong spiritual beliefs.

The causes of maritime accidents are numerous and intricate. Greater size results in corresponding increases in cargo and passenger capacity; as a result, the risk to people's lives and property increases when an accident happens. Another element that contributes to maritime mishaps is the smaller ship's reduced maneuverability due to its larger scale. Shipping accidents are a result of a number of significant factors. Natural conditions, technical difficulties, route conditions, ship-related issues, human mistake, and cargo-related factors are the most notable. There are many different types of shipping accidents, and each has a unique influence on the marine environment (Akten, 2006).

The ships are the largest vehicles of the world and equipped with state of art management systems which are mostly furnished with highly automated systems. Any automated system failure may cause fatal accidents which hamper the human life, ship and environment as well as ports and terminals. Automated systems facilitate management of the ships and reduce manpower requirement (Demirel, 2019).

Another one of the most significant challenges onboard, especially to those who work hard for the first time on sea is homesickness. It is a state of mind when individual is far away from love ones, they tend to be lonely (Ommundsen, 1991). Ommundsen said homesickness is one element of the loneliness associated with cabin crew while working.

On the other hand, ship owners are responsible for providing safe and secure working conditions, decent working and living conditions and reasonable employment terms for the satisfaction of other needs of seafarers. Offering things like competitive salaries, profit sharing, bonus programs, pension and health plans, paid leave and tuition reimbursement sends a powerful message to employees about their importance at the organization. Saks (2006) indicated that employees perceived organizational support predicts both job and organization engagement. Subsequently, it is the duty of seafarers themselves to use all the available tools to satisfy their needs. Employee's engagement like organizational commitment and organizational citizenship behavior will lead to the discretionary effort exhibited by employees in their jobs (Frank et al., 2004).

Summary.

This study assessed the influence of the seafarer's occupational profile to their lifestyle on board.

The study sought answers on the following questions:

1. What is the profile of the respondents in terms of age, gender, civil status, number of years onboard, position, license and type of vessel onboard?.
2. What are the lifestyle of the respondents in terms of:
   (a) mental/social;
   (b) spiritual; and
   (c) mental/social;
3. Is there a significant relationship between the profile of the respondents and their lifestyle?.
4. What are the challenges encountered by the seafarers while on board?.
5. What implications can be drawn from the results of the study?.

Findings.

The following are the salient finding of the study:

1. Majority of the respondents are 20 – 24 years old (36.67%), all-male (100%), primarily single (70%), whose current position is on operational level (53.33%), and mostly deck cadet (33.33%). Furthermore, most of the respondents are on board for less than one year (46.67%), and a professional license (76.67%) is not an application for them.
2. On the mental aspect, respondents had *very healthy lifestyle* as seafarers onboard; on the spiritual aspect, respondents have *a fairly healthy lifestyle* on board; while on the physical aspect, the respondents had *a very healthy lifestyle.*
3. There is a significant relationship between*the current position* and *mental* aspect of the seafarers' lifestyle and their*number of years onboard* and the*physical aspect* of the seafarers' lifestyle.

Conclusions.

This study investigated an influential factor in the quality of work life experienced by seafarers based on the mental/social, spiritual and physical aspect. The support of the family, shipping company may be the first intervention point in relieving perceived fatigue and enhancing self-efficacy, and ultimately inducing a positive impact on the quality of work life. For workers in a specific environment, such as those who work for long periods onboard a ship, the development of a health management intervention program at their workplace is necessary. Most importantly, organizational support for these health promotion programs should be made a top priority to ensure the mental and physical health of seafarers.

Recommendations.

Given the initial findings and conclusion, the following recommendations are as a result of this presented.

1. There should be good health and wellbeing seminars for every seafarer onboard to ensure individuals' good physical wellbeing.
2. The owner of shipping companies should provide enough budget for seafarer's consumption in order for them to maintain and ensure healthy nutrition on board.
3. There should be opportunities to obtain proper exercise on board.
4. International organizations in line with maritime industry should strengthen the global standards of the seafarers to maintain the good health and wellbeing of seafarers.
5. They should have a proper drill to adequate more knowledge on how to take advantage of their problem about stress from work.

References.

Journal articles

Acejo, I., 2021. The experience of being a Filipino seafarer on a multinationally crewed ship. *The World of the Seafarer*, p.99.

Akten, N., 2006. Shipping accidents: a serious threat for marine environment. *Journal of Black Sea / Mediterranean Environment*, *12*(3), pp.269-304.

Baygi, F., Jensen, O.C., Farshad, A.A., Shidfar, F. and Mohammadi - Nasrabadi, F., 2018. A qualitative study on physical health threatening factors of Iranian seafarers working on ocean going tankers. *International Maritime Health*, *69*(3), pp.192-200.

Carotenuto, A., Molino, I., Fasanaro, A.M. and Amenta, F., 2012. Psychological stress in seafarers: a review. *International maritime health*, *63*(4), pp.188-194.

Demirel, E., 2019. Possible dangers of automation failures on board and measures to avoid the negative effects of these failures. *Scientific Bulletin" Mircea cel Batran" Naval Academy*, *22*(2), pp.22A-35.

Frank, F.D., Finnegan, R.P. and Taylor, C.R., 2004. The race for talent: Retaining and engaging workers in the 21st century. *Human resource planning*, *27*(3).

Geving, I.H., Jorgensen, K.U., Le Thi, M.S. and Sandsund, M., 2007. Physical activity levels among offshore fleet seafarers. *International maritime health*, *58*(1-4), pp.103-114.

Hjarnoe, L. and Leppin, A., 2013. Health promotion in the Danish maritime setting: challenges and possibilities for changing lifestyle behavior and health among seafarers. *BMC public health*, *13*(1), pp.1-12.

Iversen, R.T., 2012. The mental health of seafarers. *International maritime health*, *63*(2), pp.78-89.

Oldenburg, M., Baur, X. and Schlaich, C., 2010. Occupational risks and challenges of seafaring. *Journal of occupational health*, *52*(5), pp.249-256.

Oldenburg, M., Jensen, H.J., Latza, U. and Baur, X., 2009. Seafaring stressors aboard merchant and passenger ships. *International journal of public health*, *54*, pp.96-105.

Ommundsen, W., 1991. The World, the Text, and the Tourist: Murray Bail's" Homesickness" as Guide to the Real. *The Journal of Narrative Technique*, *21*(1), pp.1-13.

Pukkala, E., Martinsen, J.I., Lynge, E., Gunnarsdottir, H.K., Sparén, P., Tryggvadottir, L., Weiderpass, E. and Kjaerheim, K., 2009. Occupation and cancer–follow-up of 15 million people in five Nordic countries. *Acta oncologica*, *48*(5), pp.646-790.

Saks, A.M., 2006. Antecedents and consequences of employee engagement. *Journal of managerial psychology*, *21*(7), pp.600-619.

Sampson, H. and Ellis, N., 2019. Seafarers' Mental health and wellbeing: Research report. Wigston: Institution of Occupational Safety and Health (IOSH).

Sampson, H., Turgo, N., Cadge, W., Gilliat-Ray, S. and Smith, G., 2020. Harmony of the Seas? Work, faith, and religious difference among multinational migrant workers on board cargo ships. *Ethnic and Racial Studies*, *43*(16), pp.287-305.

Web pages

Kairis, S. (2012). Seafarers Health & Lifestyle. In the Officer of the Watch. Retrieved April 22, 2019 from https://officerofthewatch.com /2012/04/22/seafarers-health-lifestyle/.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 26–33

ISSN: 1697-4840, www.jmr.unican.es

Port Performance Measurement from Perspective of Users

Satyendra Nath Chakrabartty[1,*]

ARTICLE INFO

Article history:
Received 17 Apr 2023;
in revised from 28 Apr 2023;
accepted 25 Aug 2023.

Keywords:
Port performance, Users' perspectives, perspectives, Efficiency, Normal distribution, Responsiveness.

ABSTRACT

Measurement of overall port performance need to consider expectations of customers and stakeholders. Existing methods with different sets of assumptions suffer from limitations and give different results. The paper suggests an assumptions free method of a single value of port performance measurement from users' perspectives (PPM-UP) where dimension/scale scores are transformed to follow Normal distribution, facilitating meaningful arithmetic aggregation satisfying desirable properties. The method avoids disadvantages of existing methods and helps to assess overall performance of ports and in the relevant dimensions and compares ports across time and space using statistical tests. Quantification of responsiveness of the scale using longitudinal data helps to assess effectiveness of adopted action plans. The method also helps to find growth curve of PPM- PU of a port and can be applied for any number of dimensions or K-point items K= 2, 3, 4, 5, …….. The proposed method with wide application areas advances scholarly and helps port authorities to evaluate their performance from the port users' point of view and take the necessary actions to improve it.

1. Introduction.

Assessment of efficiency of maritime transport should consider amongst others, well-functioning efficient ports (Marleny, 2020). Ports are facilitators of trade, integrators in the logistics supply chain and a channel of integration into the global economic system. A sea port is an important node of the logistics chain and its operations impact on economy and society development of a country (Tovar *et al.* 2007).

Better quality of port infrastructure helps to improve logistics performance, reduce costs (Lakshmanan, 2011), increase local and global accessibility, and opportunities to expand markets. Every ship-hour saved by ships in a port translates into benefits for ports, costs for carriers and inventory holding outlays for shippers (Thien, 2019; Sebastian, 2019). Increase in port efficiency from the 25th to the 75th percentile reduced shipping costs by 12% (Clark *et al.* 2004). Port performance measurement (PPM) is important for monitoring, achieving competitive position and managing stakeholder relationships (Ha *et al.* 2017). In fact, port is a center where large number of organizations provides different services and together creates different products (De Langen, 2008). Efficient port system with enhanced logistic abilities is a key determinant of foreign direct investment into a country (Panayides *et al.* 2015). Port inefficiencies are reflected by longer dwell time of cargo and ships, interruptions in vessel traffic clearance, protracted documentation handling, lesser handling of container per crane-hour, higher emission of GHG gases per ton of cargo, etc. (Kahyarara, 2020).

Common approaches to PPM are:

1. Relative performance using finite set of operational and financial indicators (also known as partial productivity indicators) like Physical indicators (Cargo volume, Ship traffic, Turn Around Time (TAT), Pre-Berthing Detention (PBD), Berth Occupancy, Idle time at Berth, Capacity utilization, etc.); Productivity factors (Tons per ship day, Tons per worked hour, Moves per crane hour, Tons/Moves per meter of berth length, etc.) and Financial indicators (Operating Ratio, Operating Surplus, Operating Surplus per employee, Cost per ton/TEU, etc.)

[1]Indian Statistical Institute, Indian Institute of Social Welfare and Business Management, Indian Ports Association.

[*]Corresponding author: Satyendra Nath Chakrabartty. E-mail Address: chakrabarttysatyendra3139@gmail.com.

2. Model or formula driven analytical methods to measure absolute performance reflecting joint effects of all chosen input and output variables like Best-Worst method (Rezaei, *et al.* 2018), Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), Principal Component Analysis (PCA), Analytic Hierarchy Process (AHP), etc.

The first approach speaks about supply-side of performance assessment and does not bring out the demand-side reflection, which is the users' point of view. Moreover, these partial indicators can give quite misleading results as different indicators give different rankings of ports and evaluation of interactions (joint effects) of the inputs on outputs (Estache *et al.* 2002). Varying degree of interrelationships among the indicators across time and space get changed with changes in technology, modes of operations, etc. Deployment of large container ships with reduced number of port calls results in lowering the total costs of cargo handling in the sea ports and total time required for port operations (Kowalczyk, 2012). Use of only operational and financial port performance indicators (PPIs) may not be sufficient to cover wide ranging objectives of various services offered by ports and expectations of stakeholders (Beamon, 1999).

Model driven approaches to measure port performance as a composite index (CI) involve different sets of assumptions, different methods of scaling and finding weights and even non-uniform definition and computation of indicators. However, there are different types of scaling (normalization) and each has limitations. No weighting system is above criticism (Greco *et al.* 2019). To find workers in cargo operation, Tongzon (2001) considered workers under port authorities who do not participate in cargo handling as an approximation. Martin (2002) considered stevedore workers who provide their services to stevedoring firms (carry out loading and unloading to/from ships) and the port (supply workers to the stevedoring firms). Similarly, for generated income, Liu (1995) considered the amounts received from third parties related to the port services, excluding income from the sale of goods; Martínez-Budría *et al.* (1999) also used this approach to define one of the multi-output vector components for containers. Thus, different methods gave rise to different results and different ranks to ports. In addition, non-verification of the assumptions of the methods may distort the results.

There are no universally adopted tools to measure efficiency of sea ports, despite availability of wide range of indicators for port efficiency and performance (Bichou and Gray, 2004). Measurement of port efficiency are not comparable due to non-uniformity of theoretical approaches, different time-frames, diverse ports locations and activities analyzed (Gonzalez and Trujillo, 2009). Effectiveness of ports to meet expectations of customers and stakeholders are important components that need to be included in measuring performance of ports (Brooks, 2007), keeping in mind that interests of different stakeholders vary with time and can even be contradictory. Park and De (2004) mentioned customer satisfaction as part of marketability of ports. Measuring satisfaction of port users has been advocated (Pallis and Vitsounis, 2009). A framework for assessing perceptions of port users (shipping companies, shippers, etc.) on port performance was developed by Vaggelas (2019) where a "port user" implied an entity that either consumes port services, or uses port infrastructures.

Thus, there is a need for a single measure of multi-dimensional port performance measurement from the perspective of users (PPM-PU) to assess efficiency and effectiveness of ports, evaluated by different stakeholders.

The paper suggests an assumptions-free method of obtaining a single PPM-PU value for a port by converting ordinal raw scores of a questionnaire to continuous scores following Normal distribution for meaningful arithmetic averages and satisfying the following desirable properties:

P_1 : Continuous and monotonically increasing scores where a marginal increase in an indicator will increase PPM-PU

P_2 : Avoid skew and outliers (so that there is no bias for developed or under-developed ports)

P_3 : Facilitate comparisons of various ports in terms of PPM-PU or a single port at different time periods using statistical test of equality of average PPM-PU across time and space.

P_4 : Facilitate estimation of population PPM-PU of a country or region from a representative sample of ports.

P_5 : Assess progress or deterioration of PPM-PU of a port or a group of ports by longitudinal data and undertake test of significance.

2. Literature Survey.

Impact of port performance on trade has been investigated (UNCTAD 2018a; UNCTAD 2020). A 25% improvement in port efficiency might increase growth by 2%, demonstrating close relationship between port effectiveness and trade competitiveness (Booth 2018; Niselow 2018).

Traffic handled by ports is commonly used to reflect functioning of ports (UNCTAD 2018b; Lei and Bachmann 2020; USDT, 2021). Total cargo throughput of a port is a leading economic indicator (UNCTAD 2018b). Ferrari (2011) observed positive influence of port throughput on local development but, the influence was weak (elasticity < 0.05). However, cargo volume alone cannot reflect gains from trade or improvement in total factor productivity or GDP growth (Lakshmanan, 2011).

Positive relationship exists between value-added operations at ports and economic activities (Deng *et al*. 2013). Shan *et al.* (2014) found port efficiency increased growth of a country. Yeo *et al*. (2008) found that quality of port service, logistics costs, regional connectivity, hinterland condition and port accessibility contribute significantly to a port's competitiveness. Abe and Wilson (2008) studied effect of infrastructure on trade and found port efficiency was a major determinant of trade performance.

Studies to examine relationships of port efficiency with ownership status gave mixed results. For example, Notteboom *et al.* (2000) used Bayesian Stochastic Frontier Model to 36 European and four Asian container terminals and found no clear relation between the port efficiency and the ownership status (private or public owned). Based on a sample ports of UK and

South Korea, Cullinane and Song (2003), found positive relationship between the extent of private sector participation and productive efficiency of ports. Yuen *et al*. (2013) observed that foreign participation in the ownership status of Chinese ports increased efficiency of container terminals.

Ways to measure port efficiency and performance are diverse (Ducruet *et al*. 2014). While Lirn *et al.* (2003) suggested 47 criteria on attractiveness of ports; Yeo *et al*. (2011) suggested 38 components for port competitiveness considering efficiency as a proxy of competitiveness. However, concepts of performance of a port are different from its attractiveness or competitiveness. Evaluation criteria of perceptions of Port users' like satisfaction, competitiveness, effectiveness of service delivery, etc. are different constructs (Brooks et al. 2011). PPM-PU are usually done by online survey using predetermined structured questionnaire where identified dimensions are decided based on port-sea interfaces, within port area and port-land interfaces. In addition to overall performance, a port also needs to capture performance in each dimension and relative importance of the domains.

The method of Evidential Reasoning (ER) (Yang and Xu, 2002) for multi-group multi-criteria decision making (MCDM) has been applied in the context of port choice to deal with the inherent uncertainty in a MCDM structure (Yeo *et al*., 2014). But, it did not address PPIs from various stakeholders, and failed to incorporate the interdependency among PPIs. Munim and Schramm (2018) considered the following latent constructs and indicators for a structural equation model (SEM) to examine impact of port quality on trade:

1. Quality of port infrastructure (QPI): Measured by a questionnaire consisting of 6-point Likert items from 1 to 7 to assess perceptions of business executives on port facilities where "1" and "7" represents respectively extremely underdeveloped and efficient by international standards port infrastructure (http://data.worldbank.org/indicator/-IQ.WEF.PORT.XQ).
2. Logistics performance (LP): Ability to track and trace consignments; competence and quality of logistics services; ease of arranging competitively priced shipments; efficiency of customs clearance process; frequency with which shipments reach consignee within scheduled or expected time; quality of trade and transport-related infrastructure, seeking feedbacks in Likert scales from global freight forwarders and express carrier on logistics "friendliness" of the countries in which they operate (http://lpi.-worldbank.org/).
3. Seaborne trade: Container traffic ('000 TEUs); Liner shipping connectivity index (LSCI) based on five maritime transport components: number of ships handled, their container-carrying capacity, maximum vessel size, number of services, and number of companies that deploy container ships in ports of a country (http://data.worldbank-.org/indicator/IS.SHP.GCNW.XQ).
4. National economy: GDP per capita; Purchasing power parity (PPP) (Int. $)

Considering objective factors (cost, landside accessibility, draft availability) and perception-based subjective factors (reliability, preferences, and product differentiation), Tongzon & Heng (2005) proposed port-competitiveness-index (PCI). Major limitations of PCI are (i) Measuring stakeholders' perceptions in ordinal scale with limitations and difficulties in monitoring (ii) Non-consideration of financial efficiency and sustainability efficiency and (iii) Lacks appropriate method of combining ordinal data and ratio/interval scale data.

A service's reliability is deemed as the single outcome of service transactions. But, variability in logistics services by its providers serves as a determinant of logistics quality (Dua and Sinha, 2019). Thus, reliability of port services may be considered as a composite measure in a continuous evaluation platform.

The complex autoregressive distributed lag (ARDL) model was used to investigate (i) stationary, (ii) co-integration and panel ARDL estimation (Menegaki 2019). The model requires that the error terms should have no autocorrelation with each other, no heteroscedasticity in the data. In simple terms, mean and variance should remain unchanged throughout the model and data should be normally distributed. Pesaran (2007) argued that panel unit root tests can lead to spurious conclusions if they fail to take account of significant degrees of cross-section dependence.

Vaggelas (2019) used 7-point scale to capture responses from port users on their satisfaction and also on their perceived importance. Average ratings were computed for each selected indicator or criterion for satisfaction and separately for perceived importance; differences of which were taken as GAP, without addressing methodological issues like admissibility of average rating and their differences, scale quality like reliability, validity, responsiveness, etc.

3. Problems of rating scales.

Major difficulties of Likert scales to assess perceptions / preferences of stakeholders are:

- Levels like *very often, often, once in a while, almost never* and *never* could be dubious as individuals differ on frequency of an action to consider it as often. Pertinent question is how often is *often*? (Gu *et al*. 1995)
- Ordinal discrete scores of items of Rating scales are not additive as distance between successive levels is not uniform and unknown (Munshi, 2014). Equidistant property demands constant distance between two successive levels.
- Meaningful interpretation of scores of two items say $X \pm Y$ with unknown and different distributions is difficult unless we find joint distribution of $X \pm Y$. From the measurement point of view, $X + Y = Z$ is meaningful for discrete case if

$$P(Z = z) = P(X = x, Y = z - x) \tag{1}$$

and for continuous case,

$$P(Z \le z) = P\ (X + Y \le z) = \int_{-\infty}^{\infty} (\int_{-\infty}^{z} f_{X,Y}(x,\ t-x)\, dt) dx \tag{2}$$

Thus, it is necessary to know probability density function (pdf) of each variable being added and their convolution.

- Successive levels of items are not perceived as equidistant by subjects (Lee and Soutar, 2010)
- Summative scale sore assign equal importance to the items and dimensions despite showing different values of item – total correlations and factor loadings (Parkin *et al*.2010)
- Non-satisfaction of the equidistance assumption implies non-admissibility of operations like addition. The analysis need to be limited to frequencies under item- level combinations.
- Mean, Standard deviation (SD) of Rating scales with *K*-number of levels (*K*-=3, 4, 5, 6, 7 ....) increase as *K* increases (Finn, 1972). Different values of *K* distorts shape of distribution of scores and influence item/scale parameters like Reliability, validity, and discriminating power, more by number of levels than the underlying variable (Preston and Colman, 2000; Lim, 2007).
- Different responses to different items can generate tied score for more than one respondent. Thus, the scale fails to discriminate the respondents getting same scale score.
- Empirical distribution of item scores and test scores are different and often found to be skewed.

4. Proposed Method.

Above said problem areas can be avoided by considering weighted sum where weights based on frequency of different levels of different items (Chakrabartty, 2020) are used first to convert ordinal item score to continuous equidistant scores (*E*-scores) as follows:

Consider a scale with *m*-number of dimensions where number of items in the *j*-th dimension is n_j for *j*= 1, 2, …., *m* and each item has five levels (5-point items). Suppose, *N*-respondents have answered all the items of the scale.

Step 1: Convert ordinal item raw-scores (*X*) to continuous equidistant scores (*E*-scores) by finding different weights for different levels of different items, so that for the *i*-th item,

$5W_{i5} - 4W_{i4} = 4W_{i4} - 3W_{i3} = 3W_{i3} - 2W_{i2} = 2W_{i2} - W_{i1}$ = Constant. In other words, W_{i1}, $2W_{i2}$, $3W_{i3}$, $4W_{i4}$ and $5W_{i5}$ forms an arithmetic progression with common difference $b > 0$.

Let frequencies of different levels of the *i*-th item are $f_{i1}, f_{i2}, f_{i3}, f_{i4}$ and f_{i5}. Choose maximum ($f_{i\ Max}$) and minimum frequency ($f_{i.\ Min}$). Take initial weights $\omega_{ij} = \frac{f_{ij}}{N}$ and arrange $\omega'_{ij}s$ so that $\omega_{i1} < \omega_{i2} < \omega_{i3} < \omega_{i4} < \omega_{i5}$ where $\omega_{i1} = \frac{f_{i.Min}}{N}$ and $\omega_{i5} = \frac{f_{i.Max}}{N}$.

Take intermediate weight $W_{i1} = \omega_{i1}$ and find common difference *b* so that

$$W_{i1} + 4b = 5W_{i5} \Longrightarrow b = \frac{5f_{i.Max} - f_{i.Min}}{4N}$$

Thus, $W_{i2} = \frac{\omega_{i1} + b}{2}$, $W_{i3} = \frac{\omega_{i1} + 2b}{3}$; $W_{i4} = \frac{\omega_{i1} + 3b}{4}$; and $W_{i5} = \frac{\omega_{i1} + 4b}{5}$.

Final weights are computed as $W_{ij(Final)} = \frac{W_{ij}}{\sum_{j=1}^{5} W_j}$ so that $\sum W_{ij(Final)} = 1$ and $j.W_{j(Final)} - (j-1).W_{(j-1)(Final)} =$ constant, value of which will be different for different items.

E-scores as weighted sum are continuous and equidistant and can be used for any item with different number of levels. $b > 0$ ensures monotonic nature of *E*-scores of items. The situation $f_{ij} = 0$ for a particular *j*-th level of an item can be taken as zero value for scoring Likert items as weighted sum.

However, there could be other way to convert raw item scores (X) to *E*-scores. For example, weights could be based on area under $N(0,1)$ with $W_i > 0$ and $\sum_{i=1}^{5} W_i = 1$. Procedure for obtaining $W'_j s$ of an item considering area under $N(0,1)$ is illustrated in Table 1.

Table 1: Calculation of weights based on area under N (0,1).

Response Category	Proportion (p_i)	Cumulative Proportions (C_i)	Area under the standard Normal curve	Initial Weights
1	$p_1 = \frac{f_1}{mn}$	p_1	$A_1 = Upto\ p_1$	$\omega_1 = \frac{A_1}{\sum A_i}$
2	$p_2 = \frac{f_2}{mn}$	$p_1 + p_2$	$A_2 = Upto\ p_1 + p_2$	$\omega_2 = \frac{A_2}{\sum A_i}$
3	$p_3 = \frac{f_3}{mn}$	$p_1 + p_2 + p_3$	$A_3 = Upto\ p_1 + p_2 + p_3$	$\omega_3 = \frac{A_3}{\sum A_i}$
4	$p_4 = \frac{f_4}{mn}$	$p_1 + p_2 + p_3 + p_4$	$A_4 = Upto\ p_1 + p_2 + p_3 + p_4$	$\omega_4 = \frac{A_4}{\sum A_i}$
5	$p_5 = \frac{f_5}{mn}$	$p_1 + p_2 + p_3 + p_4 + p_5 = 1.00$	$A_5 = Upto\ p_1 + p_2 + p_3 + p_4 + p_5$	$\omega_5 = \frac{A_5}{\sum A_i}$
Total	1.00		$\sum_{i=1}^{5} A_i > 1$	1.00

Source: Author.

Here, $\omega_j > \omega_{j-1}$ for *j*= 2,3,4,5. Thus, the monotonic condition is satisfied. However, to make the transformed scores equidistant for a 5-point scale, divide the difference between Maximum area and the Minimum area by 3 and call it the correction factor α. Determine the modified areas $\Delta_1, \Delta_2, \Delta_3, \Delta_4$ and Δ_5 as follows:

$\Delta_1 = A_1$(unchanged), $\Delta_2 = \Delta_1 + \alpha$; $\Delta_3 = \Delta_2 + \alpha$; $\Delta_4 = \Delta_3 + \alpha$; $\Delta_5 = \Delta_4 + \alpha$

Define corrected weights $W_j = \frac{\Delta_j}{\sum_{j=1}^{5} \Delta_j}$ Transformed scores based on corrected weights so defined satisfy the monotonic condition, ensures equidistant scores and also satisfy $\sum_{j=1}^{5} W_j = 1$.

It may be noted that weights to the response-categories are different for different items for the Method based on frequency of each response - category but, weights to various response-categories remain unchanged across items in Method based on area under $N(0,1)$. Thus, the former method appears to be more rigorous and preferable.

Step 2: Standardize *E*-scores of *i*-th item as $Z_i = \frac{E_i - \overline{E_i}}{SD(E_i)} \sim N(0,\ 1)$ where $-\infty \le Z_i \le \infty$.

Step 3: To ensure positive scores and uniformity in score–

range, transform Z_i to proposed score P_i by

$$P_i = (100 - 1)\left[\frac{Z_i - MinZ_i}{MaxZ_i - MinZ_i}\right] + 1 where 1 \leq P_i \leq 100 \quad (3)$$

Thus, both individual scores and item scores are in terms of expected values and hence each is continuous satisfying following conditions of linearity, for constants α and β:

$E\ (x + y) = E(x) + E(Y)$

$E\ (\alpha x) = \alpha E(x)$

$E\ (\alpha x + \beta y) = \alpha E(x) + \beta E(y)$

Normally distributed P_i-scores of the items belonging to a dimension can be added to get the Dimension scores. Sum of the dimension scores or equivalently sum of all item-wise P_i-scores will be the scale scores. Dimension scores as well as Scale scores will follow normal. If scores of the i-th dimension $\sim N\ (\mu_i,\ \sigma_i)$, scale scores also follow normal with mean $\sum_i \mu_i$ and variance $[\sum \sigma_i^2 + 2\sum_{i\neq j} Cov(D_i, D_j]$ which can be estimated from the data. Thus, probability density function (pdf) of scale scores as convolution of item-wise normally distributed P_i-scores can be found where parameters of the distribution can be estimated from the data

E-scores and *P*-scores consider pattern of responses unlike raw scores (*X)* and give unique ranks to the individuals. Chakrabartty and Sinha (2022) gave example of zero tied scores in *E*-scores and *P*-scores when X = 23 for each of seven persons.

4.1. Benefits of the proposed method:

1. Conversion of raw scores to normally distributed scores can be done irrespective of number of items in a dimension and number of response-category of items.
2. Possible to find dimension sores (D_i) indicating performance in the dimension and scale scores (S) reflecting overall performance of a port (PPM- PU) through better admissibility of arithmetic aggregation.
3. Dimension scores and total scores are continuous, monotonic, normally distributed and help to undertake parametric analysis including estimation of population mean (μ), population variance $\left(\sigma^2\right)$, from a representative sample of ports of a country or region. The method helps to test hypothesis of equality of means and variances like $H_0 :\ \mu_1 = \mu_2$ or $H_0 :\ \sigma_1^2 = \sigma_2^2$ either for longitudinal data or snap-shot data.
4. *P*-score reduces drastically number of tied scores and provide unique ranks to the ports and thus, help in better ranking of ports
5. Contribution of a dimension to PPM-PU is given by

$$Contribution_{i-th\ Dimension} = \frac{D_i}{S} \times 100 \quad (4)$$

6. Percentage progress/deterioration of the i-th port in t-th time-period over the previous year can be assessed by Percentage progress:

$$\%Progress = \frac{(PPM - PU)_{it} - (PPM - PU)_{i(t-1)}}{(PPM - PU)_{i(t-1)}} \times 100 \quad (5)$$

which quantifies responsiveness of the entire scale and effectiveness of adopted action plan. $(PPM - PU)_{it} > (PPM - PU)_{i(t-1)}$ implies progress in t-th period over (t-1)-th period. Deterioration, if any may be probed to identify the dimension(s) where deteriorations occurred and extent of deteriorations for possible corrective actions. Similarly, progress for a group of ports is reflected if

$$\overline{(PPM - PU)_{it}} > \overline{(PPM - PU)_{i(t-1)}} \quad (6)$$

7. Statistical tests of significance of progress in a dimension or PPM-PU can be tested $H_0 :\ \frac{D_{it} - D_{i(t-1)}}{D_{i(t-1)}} = 0$ or $H_0 :\ \frac{(PPM-PU)_{it} - (PPM-PU)_{i(t-1)}}{(PPM-PU)_{i(t-1)}}$ since ratio of two normally distributed variables follows χ^2 distribution
8. Plotting of progress/deterioration of a port across time helps to compare progress pattern that is, response to the corrective measures adopted from the beginning of the longitudinal study.
9. Normality helps to estimate variance of each item and variance of the scale and thus enables estimation of scale reliability by Cronbach alpha at population level.
10. Normality distributed scores satisfy the basic assumption of PCA and computation of factorial validity as $\frac{\lambda_1}{\sum \lambda_i}$, where λ_1 is the highest eigenvalue associated with the first principal component. Factorial validity reflects the main factor for which the scale was developed and accounts for $\frac{\lambda_1}{\sum \lambda_i} \times 100$ percent of overall variability. Such factorial validity from single administration of a test avoids the problems of construct validity and is independent of criterion scale (Parkerson, *et al*. 2013).

5. Discussion.

Dimensions-wise performance of ports goes beyond handling operations at the berths and terminal areas. However, selection of dimensions and items within a dimension need to be decided keeping in mind multi-dimensional nature of port performance, considering changing roles of the ports to its customers and stakeholders, global competition replacing local competitions, adaptation of market economies which demand lowering costs including logistics cost, induction of technology in navigability and loading and discharging process, role played as a node in supply – change management, Rail – Road – IWT connectivity and Dry Port interfaces, environmental and climate related issues, etc. If needed, corporate social responsibility (CSR) on ports can be added as additional dimension. It can be assumed that ports are continuously trying to measure and improve their performances in the selected dimensions. In short, dimensions of the port performance need to bring a well-fitted perception to the modern port performance concept.

Items within a dimension can be selected by pilot study where a large pool of items is administered to a group of expert stakeholders, ensuring that choice of higher response-category implies better performance. Heuristic approach may be used to delete the items in stages where (i) agreement≤ 25 per cent implying ambiguity or difficulty to understand (ii) agreement in

one response-category≥70 per cent since such items had poor discriminating abilities (iii) increase in Cronbach's alpha with addition of the item. In other words, delete the j-th item if $\alpha_j \geq \alpha_{j-1}$ where α_j denotes reliability of the dimension (sub-test) with j-items and α_{j-1} denotes reliability of the sub-test with (j-1) items. If deletion of an item increases alpha of the sub-test, the item needs to be deleted from the questionnaire.

Responsiveness of the scale is quantified by value of progress / decline of one port or a group of ports by $\frac{P_{i_{t_{j+1}}}}{P_{i_{t_j}}}$ or equivalently by $\frac{P_{i_{t_{j+1}}} - P_{i_{t_j}}}{P_{i_{t_j}}} \times 100$. Each can take positive or negative value depending on $P_{i_{t_{j+1}}} > P_{i_{t_j}}$ or $P_{i_{t_{j+1}}} < P_{i_{t_j}}$. Significance of progress or deterioration can be tested statistically since ratio of two normally distributed variable follows χ^2 distribution.

Relative importance of the dimensions to influence the scale scores is essentially the effect of small change in i-th dimension (D_i) to scale score (P_{Scale}) and can be quantified in terms of elasticity that is percentage change of P_{Scale} due to small change inD_i. The dimensions can be ranked based on such dimension-wise elasticity. Elasticity studies in reliability engineering, economics often consider model like $logQ_{jt} = \alpha_j + \beta_j logP_{jt}$ where Q_{jt} denotes the quantity demanded of j-th industry at time t and P_{jt} is industry price relative to the price index of the economy. However, for P-scores following normal, logarithmic transformations are not required to fit regression equation of the form $P_{Scale} = \alpha_i + \beta_i D_i + \varepsilon_i$ where $\beta_i = r_{P_{Scale},\, D_i} [\frac{SD(P_{Scale})}{SD(D_i)}]$. The coefficient β_i reflects the impact of a unit change in the independent variable (i-th dimension) on the dependent variable (P_{Scale}). However, these coefficients are not elasticity's. Convention of a meaningful estimate of elasticity is to consider it at the point of means, since all regression lines pass through the point of means. Elasticity of the independent variable D_i for a regression equation of P_{Scale} on $D_i's$, can be written as $\frac{\frac{\Delta P_{Scale}}{P_{Scale}}}{\frac{\Delta D_i}{D_i}} = \frac{\Delta P_{Scale}}{\Delta D_i} \frac{D_i}{P_{Scale}} = \beta_i \frac{D_i}{P_{Scale}}$ where β is the slope of regression line $Q = \alpha + \sum \beta_i D_i$. Thus, elasticity of the i-th dimension $e_i = \beta_i \frac{Mean\ (D_i)}{Mean(P_{Scale})}$. The dimensions can be arranged by increasing order of elasticity (e_i). Policy makers can decide appropriate actions in terms of continuation of efforts towards the dimensions with high values of elasticity and corrective actions for the dimensions with lower elasticity that is, areas of concern. However, high correlation between a pair of dimensions indicates presence of multicolinearity which indicates overlapping between the two dimensions and may not be desirable. PCA or FA may result in lesser number of independent factors than the number of dimensions considered since some of the dimensions may be correlated.

Conclusions

The paper suggests a simple assumptions free method of obtaining a single PPM - PU value for a port considering multi-criteria goals, and relevant components by converting ordinal raw scores of items of a questionnaire to continuous scores following Normal distribution for meaningful arithmetic averages and satisfaction of desirable properties. The method helps the port planners to know overall performance of ports from the users' point of view along with performances in the relevant dimensions and compare the ports across time and space using statistical tests. Quantification of responsiveness of the scale using longitudinal data helps to assess effectiveness of adopted action plans.

The proposed method avoids disadvantages of existing methods which are either not methodologically sound or involve assumptions, verification of which are required before application of the methods. The method helps to find the growth curve of PPM- PU of a port, which in turn provides another criterion for comparison among ports. The method can be applied even for skewed raw data with any number of dimensions containing different number of K-point items K= 2, 3, 4, 5 …However, the proposed method requires careful preparation of the scale covering dimensions and items within a dimension.

The proposed method with wide application areas satisfying desired properties advances scholarly and the proposed method could help port authorities to evaluate their performance from the port users' point of view and take the necessary actions to improve it. Future empirical studies may be undertaken with additional sustainable sub-indicators like emission per ton cargo handled and energy consumed per ton cargo handled to prescribe effective and implementable standards for improving PPM-PU and indication of impact if the prescribed measures are implemented.

References.

Abe, K., and J. S.Wilson (2008): Trade, Transparency, and Welfare in the Asia Pacific. *Journal of International Economic Studies* 12: 35–87.

Beamon, B.M.(1999): Measuring supply chain performance. *International Journal of Operations & Production Management*, 19(3), 275-292.

Bichou and Gray (2004): A Logistics and Supply Chain Management Approach to Port Performance Measurement, *Maritime Policy and Management*. 31(1), 47-67.

Booth, L. (2018): Ports Critical for Growth in Africa. Retrieved from: https://www.commercialriskonline.com/ports-critical-growth-africa/.

Brooks, M.R. (2007): Issues in measuring port devolution program performance: a managerial.

Perspective, in Brooks, M.R. and Cullinane, K. (Eds), *Devolution, port governance and port performance,* Elsevier, London, 599-629.

Brooks, M.R., Schellinck, T. and Pallis, A.A. (2011): A systematic approach for evaluating port Effectiveness. *Maritime Policy and Management*, 38(3), 315-334.

Chakrabartty, SN and Sinha, D (2022): Assessing a Country's Sector-specific Logistics Performance: The case of India's Marine-product Sector. Under publication - Journal of Maritime Logistic.

Chakrabartty, Satyendra Nath (2020): Reliability of Test Battery. *Methodological Innovations*, 1–8. DOI: 10.1177/2059-799120918340.

Clark, X., D. Dollar, and A. Micco (2004): Port efficiency, maritime transport costs, and bilateral trade. *Journal of Development Economics* 75: 417–50.

Cullinane, K. P.B. and Song, D. W. (2003): A stochastic frontier model of the productive efficiency of Korean container terminals. *Appl. Econ.*, 35: 251–267.

Deng, P., S. Lu, and H. Xiao (2013): Evaluation of the relevance measure between ports and regional economy using structural equation modeling. *Transport Policy* 27: 123–33.

De Langen, P.W. (2008): Port performance indicators, ESPO Conference, Bilbao.

Dua, A., & Sinha, D. (2019): Assessment of quality of multimodal transportation for containerized exports. *IIM Kozhikode Society & Management Review*, 8(1), 10-22.

Ducruet, C., H. Itoh, and O. Merk (2014): Time Efficiency at World Container Ports. http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP201408.pdf

Estache, Antonio & Trujillo, Lourdes & González, María. (2002): Efficiency Gains from Port Reform and the Potential for Yardstick Competition: Lessons from Mexico. *World Development.* 30. 545-560. 10.1016/S0305-750X(1)00129-2.

Ferrari, Claudio (2011): Ports and regional economic development: Global Ports and Urban Development: Challenges and Opportunities, OECD, Paris

Finn, R.H. (1972): Effects of some variations in rating scale characteristics on the means and reliabilities of ratings. *Educational and Psychological Measurement*, 32(7), 255–265.

Gonzalez, MM. and Trujillo, L.(2009): Efficiency measurement in the port industry: a survey of the empirical evidence, *Journal of Transport Economics and Policy,* 43, 157-192.

Greco, S., Ishizaka, A., Tasiou, M. and Torrisi, G. (2019): On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation and Robustness, *Soc Indic Res.* 141:61–94 10.1007/s11205-017-1832-9.

Gu, Y, Wen, Q and Wu, D.(1995): How Often Is Often? *English Language Teaching;* 5, 19-35

Ha, M. H., & Yang, Z. (2017): Comparative analysis of port performance indicators: Independency and interdependency. *Transportation Research Part A: Policy and Practice*, 103, 264-278.

Kahyarara, G.(2020): Investment in Port Infrastructures across Africa Coastlines. Retrieved from: https://allafrica.com/stories/202008 260455.html

Kowalczyk, Urszula (2012): Case Study on Hub - And - Hinterland Development In The Baltic Sea Region, Maritime Institute in Gdansk, TransBaltic Project, Gdansk, Poland 2012

Lakshmanan T (2011): The broader economic consequences of transport infrastructure investments. *J Transp Geogr* 19(1): 1–12.

Lee JA and Soutar G. (2010): Is Schwartz's value survey an interval scale and does it really matter? *J Cross-Cultural Psychol*; 41: 76–86.

Lei, C., and Bachmann, Q. (2020): Assessing the role of port efficiency as a determinant of maritime transport costs: Evidence from Canada. *Maritime Economics & Logistics* 22: 562–84.

Lim, Hock-Eam (2007): The Use of Different Happiness Rating Scales: Bias and Comparison Problem? *Soc Indic Res*. 87:259–267.

Lirn, T. C., Thanopoulou, H.A. and Beresford, A. K. C. (2003): Transshipment port selection and decision making behavior: analyzing the Taiwanese case, *International Journal of Logistics,* 6(4), 229-244.

Liu, Z. (1995): The comparative performance of public and private enterprises. *Journal of Transport Economics and Policy*, 29:263-274.

Marleny, A. (2020): UNCTAD says Maritime Transport of Goods Helps Minimise Covid-19 Economic Impacts. Retrieved from: https://www.engineeringnews.co.za/article/unctad-says-maritime-transport-of-goods-help-minimise-covid-19-economic-impacts-2020-03-26.

Martín, M. (2002): El sistema portuario español: regulación, entorno competitivo y resultados. Una aplicación del análisis envolvente de datos, Ph.D. Thesis, Universitat Rovira I Virgili.

Martinez-Budria, E., Diaz-Armas, R., Navarro-Ibafiez, M. and Ravelo-Mesa, T. (1999): A study of the efficiency of Spanish port authorities using data envelopment analysis. *International Journal of Transport Economics*, 2:237-253.

Menegaki, A. N. (2019): The ARDL Method in the Energy-Growth Nexus Field; Best Implementation Strategies. *Economies* 7: 105.

Munim, Z. H., and H. Schramm (2018): The Impacts of Port Infrastructure and Logistics Performance on Economic Growth: The Mediating Role of Seaborne Trade. Retrieved from: https://-jshippingandtrade.springeropen.com/articles/10.1186/s41072-018-0027-0.

Munshi, Jamal (2014): A Method for Constructing Likert Scales. *SSRN Electronic Journal*. 10.2139/ssrn.2419366.

Niselow, T. (2018): Port of Durban Likely to Emerge as One of Africa's Major Hubs-PwC. Retrieved from: https://www.fin24-.com/Economy/port-of-durban-likely-to-emerge-as-one-of-africas-majorhubs-pwc-20180413.

Notteboom, T., Coeck, C. and Van Den Broeck, V. (2000): Measuring and explaining the relative efficiency of container terminals by means of Bayesian stochastic frontier models, *International Journal of Maritime Economics*, 2(2), 83-106.

Pallis, AA. and Vitsounis, TK. (2009): Port performance: measuring port users' perspectives, WCTR Conference – Special Interest Group 2, University of Antwerp.

Panayides PM, Parola F, Lam JSL (2015): The effect of institutional factors on public–private partnership success in ports. *Transp Res A Policy Pract* 71:110–127.

Park, RK and De, PF (2004): An alternative approach to efficiency measurement of Seaports, *Maritime Economics and Logistics*, 6, 53–69.

Parkerson HA, Noel M, Pagé MG, Fuss S, Katz J, Asmundson GJ (2013): Factorial Validity of the English Language Version of the Pain Catastrophizing Scale Child Version, *The Journal of Pain,* 14(11), 1383-1389, https://doi.org/10.1016/j.jpain.-2013.06.004.

Parkin D, Rice N, Devlin N.(2010): Statistical analysis of EQ-5D profiles: does the use value sets bias inferences? *Med Decis Making* 30(5):556–565.

Pesaran, M. H. (2007): A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics* 22: 265–312.

Preston, CC and Colman, AM. (2000): Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences, *Acta Psychologica,* 104, 1-15.

Rezaei J, Palthe LVW, Tavasszy L, Wiegmans B, Laan FVD. (2018): Port performance measurement in the context of port choice: an MCDA approach. *Management Decision*, 57(2), 396-417. 10.1108/MD-04-2018-0482.

Shan, J., M. Yu, and C. Lee (2014): An empirical investigation of the seaport's economic impact: Evidence from major ports in China. *Transportation Research Part E* 69: 41–53.

Sebastian, B. (2019): Data Supporting Swifter Shipping. https://www.marinetraffic.com/blog/data-supporting-swifter -shipping/.

Thien, D.(2019): Digital Ports Way of the Future. Retrieved from: http://www.dailyexpress.com.my/news/142467/digital-ports-wayof-the-future/.

Tongzon, J. (2001): Efficiency measurement of selected Australian and other international ports using DEA. *Transportation Research Part A*, 35:113-128.

Tongzon, J., & Heng, W. (2005): Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals).*Transportation Research Part A: Policy and Practice*, 39(5), 405-424.

Tovar, Beatriz; Jara-Díaz, Sergio and Trujillo, Lourdes (2007): Econometric estimation of scale and scope economies within the Port Sector: a review, *Maritime Policy & Management,* 34:3, 203-223, DOI: 10.1080/03088830701342932

UNCTAD (2020): Review of Maritime Transport, New York Highlights and Figures on Africa. Retrieved from: https://unctad-.org/system/files/official-document/rmt2020_en.pdf

UNCTAD (2018a): Maritime Trade and Africa. Retrieved from: https://unctad.org/pressmaterial/maritime-trade-and-africa.

UNCTAD (2018b): Review of Maritime Transport Retrieved from: https://unctad.org/system/files/official-document/rmt2018-ch4_en.pdf

United States Department of Transportation (2021): Measures of Throughput and Capacity. Retrieved from: https://www.-bts.gov/archive/publications

Vaggelas, George K. (2019): Measurement of port performance from users' perspective. *Maritime Business Review*; 4 (2); 130-150. DOI 10.1108/MABR-08-2018-0024

Yang, J.B., Xu, D.L. (2002): On the evidential reasoning algorithm for multiattribute decision analysis under uncertainty. *IEEE Transactions on Systems, Man, and Cybernetics Part A: Systems and Humans* 32(3), 289–304.

Yeo, Gi-Tae; Ng, A.K.Y., Lee. PTW & Yang. Z. (2014): Modelling port choice in an uncertain environment, *Maritime Policy & Management*, 41:3, 251-267. DOI: 10.1080/03088839.-2013.839515

Yeo, G.T., Roe, M. and Dinwoodie, J. (2011): Measuring the competitiveness of container ports: logisticians perspectives*, European Journal of Marketing*, 45(3), 455-470.

Yeo, G. T., M. Roe, and J. Dinwoodie (2008): Evaluating the competitiveness of container ports in Korea and China. *Transportation Research Part A: Policy and Practice* 42: 910–21.

Yuen, A.C.L., Zhang, A. and Cheung, W. (2013): Foreign participation and competition: a way to improve the container port efficiency in China? *Transportation Research Part A*, Vol. 49, 220-231.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 34–45

ISSN: 1697-4840, www.jmr.unican.es

All Hands on Deck: Ensuring Sustainability in Philippine Maritime Education through Global Standards Compliance

C.J. Agbing[1], J.S. Chua[1], C.C. Discaya[1], E.III. Gochan[1,*], S.M. Osmeña[1]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 24 Jun 2023;
accepted 16 Jul 2023.

Keywords:
Maritime education and training,
Philippine maritime industry,
Sustainability, EMSA.

ABSTRACT

The European Maritime Safety Agency (EMSA) flagged the Philippines for noncompliance with STCW (Standards of Training, Certification, and Watchkeeping) requirements. The Philippines' failure to improve their Maritime Education and Training (MET) puts the country's eligibility for Filipino seafarers' employability at risk. Data obtained from interviews with a partner maritime institution will be used to evaluate if the partner institution complies with the Maritime Industry Authority (MARINA) adjustments and EMSA's requirements by looking at the second key area. The researchers used legal frameworks and management frameworks (internal and external factor evaluation) to assess the partner institution's performance. Even if the Philippines has just recently passed the EMSA audit, this paper would be beneficial to continue improving Philippine MET to avoid negative future international audits. Overall, the researchers recommend that the partner institution reinstate its BS in Marine Engineering and Electro-technology program, that the maritime industry develops its training programs and governance system, and that future researchers include all six key areas to provide a better assessment of the industry's sustainability.

1. Chapter One.

1.1. Background of the Study.

Throughout increasing globalization, the maritime industry has been a crucial component. With more than 90% of global goods undergoing maritime trade, the demand for maritime transport is expected to triple the current maritime trade volume by 2050.[2] As an archipelago, the Philippines has a significant role in establishing a coordinated maritime transport network for commerce and travel.[3] Among the countries supplying maritime labor, the Philippines leads with ~30% of the global maritime seafarer supply.[4]

Through Republic Act No. 10635, MARINA serves as the single maritime administration that is responsible for development throughout the Philippine maritime industry.[5] Four major sectors characterize the industry: domestic shipping, overseas shipping, shipbuilding and repair, and maritime staffing and development.[6] In the area of maritime staffing, the remittances of

[1]John Gokongwei School of Management Department. Ateneo de Manila University.

[*]Corresponding author: Esteban III Gochan. E-mail Address: esteban.gochan@obf.ateneo.edu.

[2] Organisation for Economic Co-operation and Development, Ocean Shipping and Ship Building, available at https://www.oecd.org/ocean/topics/ocean-shipping/ (last accessed February 2, 2023).

[3] United Nations Economic and Social Commission for Asia and the Pacific, The Philippine Maritime Industry: Prospects and Challenges in 2013 and Beyond, at 1, available at https://www.unescap.org/sites/default/files/0.Philippines-1.pdf (last accessed February 2, 2023).

[4] Oxford Business Group, Filipinos are Active in the Global Maritime Sector, available at https://oxfordbusinessgroup.com/reports/philippines/2015-report/economy/seafaring-nation-filipino-workers-have-become-an-essential-part-of-the-global-maritime-industry (last accessed February 2, 2023).

[5] An Act Establishing the Maritime Industry Authority (MARINA) as the Single Maritime Administration Responsible for the Implementation and Enforcement of the 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, as amended, and International Agreements or Covenants Related Thereto, Republic Act No. 10635, § 3 (2013).

[6] Maritime Industry Authority, MARINA Statistical Report 2017-2021, at

Filipino seafarers have contributed 9.8% of the country's total Gross Domestic Product (GDP).[7]

Recent developments have raised concerns about the quality of the staffing the Philippines supplies. For the past 16 years, the European Maritime Safety Agency (EMSA) warned the Philippines regarding their noncompliance with STCW (Standards of Training, Certification, and Watchkeeping) requirements.[8] Since 2006, the Philippines failed to adapt fully, placing the country in a precarious situation, risking being excluded from the International Maritime Organization's (IMO's) "whitelist" of nations with seafarer employability.[9] MARINA has issued its response to the audit, which contains in-depth reviews of the state of maritime education in maritime schools and the strategic corrective actions.[10]

1.2. Statement of the Problem.

Prioritizing the labor sector, the International Labor Organization (ILO) and the IMO work together to set labor standards, enhance social protection, and promote rights at work for over 400,000 Filipino seafarers. In 2022, IMO and ILO established the ILO – IMO Tripartite Working Group to Identify and Address Seafarers' Issues and the Human Element (JTWG). Through its audit, the EMSA, a European Union regulatory agency that creates a safe, secure, green, and competitive maritime sector, has also identified issues concerning the country's capability in the industry. All of these agencies act in a regulatory manner, with non-compliance with their standards possibly leading to repercussions and disruption of the Philippine supply of maritime workforce.

MARINA was created to integrate the development, promotion, and regulation of the country's maritime industry.[11] Despite its progressive efforts to achieve such vision and goals, the European Commission (EC), through the EMSA, released an assessment report on the Philippines' maritime education, training, and certification system. The report listed nine shortcomings and twenty-three grievances, supplemented by recommendations to redress the report's findings and sustain long-term reforms.

With MARINA's newly mandated policies submitted in response to the findings above, **this thesis looks into the sustainability aspect of such policies – whether or not these would consistently develop and improve the country's MET system.** Specifically, this paper will focus on the maritime programs offered by the partner institution as it aims to answer the question: "How does aligning the country's maritime educational, training, and certification systems with the STCW Code contribute to the sustainability of the Philippine maritime industry?"

1.3. Thesis Statement.

The study's thesis statement is as follows:

"A Philippine Maritime Education Institute that is aligned with the STCW ensures sustainability by guaranteeing quality seafarers, who have the skills and abilities to be trained and employed following international standards. Such alignment with international standards allows the Philippine Maritime Education to be worth investing in through improved maritime training and assessment achievable by continuous monitoring and evaluation."

1.4. Research Methodology.

1.4.1. Data Gathering Technique.

Most of the data gathering will be in the form of a literature review of relevant data from the standards set by the EMSA and data for other factors from the partner institution through interviews.

1.4.2. Data Gathering Procedure.

Most of the data collected will be from online sources, including EMSA standards. For the interviews, the researchers will contact relevant personalities from the partner institution to gather data to complete the research.

1.4.3. Data Analysis.

After collecting all relevant data, the researchers will compare the standards set by EMSA to the partner institution. Through this, the researchers may find gaps and inconsistencies to propose recommendations for the target institution to be on par with the standards set by EMSA.

1.5. Review of Related Literature.

1.5.1. 2022 Philippine Response.

The Philippines' response to EMSA's audit is detailed in MARINA's 2022 report, where each grievance is countered with the corrective actions taken. One of the critical areas for improvement and compliance is the monitoring, supervision, and evaluation of training and assessment.[12] The deficits in this key area include the MHEIs not planning the courses, not following the lesson schedules or timetables, not carrying out the practical training outlined in the course syllabi, not systematically recording students' attendance, and not admitting students to

2, available at https://marina.gov.ph/wp-content/uploads/2022/06/2017-2021-MARINA-Statistical-Report-1.pdf (last accessed February 2, 2023).

[7] Technical Education and Skills Development Authority, The Philippine Maritime Industry Through the Years, at 12, available at https://www.tesda.gov.ph/Uploads/File/planning2017/LMIR/MARITIME%20-LMIR%20March%2017%20with%20cover%202017.pdf (last accessed February 2, 2023).

[8] Karl Garcia, Some Observations on Philippine Maritime Education, The Maritime Review, November 26, 2021, available at https://maritimereview.ph/some-observations-on-philippine-maritime-education/ (last accessed February 2, 2023).

[9] Philstar Global, Philippines Corrects Course to Meet Global Seafarer Training Standards, Philstar, November 17, 2022, available at https://www.philstar.com/headlines/2022/11/17/2224535/philippines-corrects-course-meet-seafarer-training-standards (last accessed February 2, 2023).

[10] Maritime Industry Authority, 2022 Philippine Response, available at https://marina.gov.ph/wp-content/uploads/2022/06/2022-PHILIPPINE-RESPONSE.pdf (last accessed February 2, 2023).

[11] Id. at 2.

[12] Maritime Industry Authority, supra note 10.

courses according to the MHEI's carrying capacity.[13] To address these, CHED-MARINA required MHEIs to submit a corrective action plan. They also issued a memorandum (instructing MHEIs to revise their teaching syllabi) elaborating additional student attendance policies and ensured better monitoring and supervision of MHEIs. Carrying capacity computations and the list of equipment per MHEI were reviewed. Moreover, an Annual Monitoring Program of MHEIs will be implemented to use the monitoring results as a basis for improvement. The study presents the factors contributing to the results of the EMSA audit and CHED-MARINA's procedures to address these issues.

1.5.2. The 1978 International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW).

The 1978 STCW Convention, established by the IMO, was the first to establish basic requirements for the training, certification, and watchkeeping for seafarers on an international level. The Philippines has been a cooperative member of the IMO since 1964 as it observes and enforces the rules on the safety and security of shipping.[14] The Convention prescribes minimum standards that member states must meet or exceed. Additionally, the STCW was created to improve worldwide education, training, and safety standards. The research will primarily focus on the STCW Convention as its basis for identifying whether MARINA's new policies ensure the sustainability of the maritime industry.

1.5.3. The Challenges In Philippine Maritime Education and Training.

The challenges the Philippines faces regarding their MET are the global supply and demand market and compliance with the STCW Convention.[15] As the Philippines is one of the world's leading suppliers of maritime workers, compliance with the STCW Convention and Code is to be given utmost importance for the safety and security of Filipino seafarers.

The research states that the difficulties in Philippine MET can be divided into two parts. The first stipulated that Philippine MET must be compliant with the requirements of the international maritime rules. The second cites the improvement of MET in the Philippines. The government has already established a body called the National Quality Standard System (NQSS) that combines the quality standards of all maritime-involved agencies such as the Philippine Regulation Commission (PRC), Technical Education Skills Development Authority (TESDA), Commission on Higher Education (CHED), and the National Telecommunications Commission (NTC).[16] The second part would be harder to address due to factors such as the consistent pressure applied on training institutions to match international standards as well as the requirement for a "strong commitment" by all collaborators in the maritime industry.[17]

1.5.4. Improving governance of maritime higher education institutions.

The success of Filipino cadets is scarce, as indicated by low MET Institutions' success rates.[18] In 2020, only 17% of Filipino marine cadets had an embarkation opportunity and were able to work as seafarers.[19] This is due to an inconsistency between MARINA's policies and the performance of METIs and a low level of supervision and regulation by MARINA. MARINA's system of governance in MET must be reviewed to comply with STCW standards. Quality education in the Philippine METIs must be provided and monitored to increase cadet opportunities.[20]

1.6. Scope and Limitations.

The scope of the study shall include the state of the Philippine maritime educational system and its gaps with international standards and focus on a partner Philippine MHEI that is accredited to offer maritime degree programs. Given the extensive key areas evaluated by the EMSA as a global accrediting body, the study shall look in depth at the specific key area of Monitoring, Supervision, and Evaluation of Training and Assessment. The said key area should include the following aspects: course outlines, training schedules and attendance, and carrying capacities.

The study shall be limited to the online data and the institution's responses. The researchers bore no control over the willingness of the partner institution to participate and their answers. The study shall only be used to evaluate compliance with the standards set by the MARINA. As such, the results of this study shall be interpreted toward the level of compliance of the specific institution alone.

2. Chapter Two.

2.1. Legal Framework.

2.1.1. 1987 Philippine Constitution.

Article XII Section 14 (sustained development of national talents). This section states that "The sustained development of a reservoir of national talents…in all fields shall be promoted by the State." The state shall encourage appropriate technology and regulate its transfer for the national benefit."[21] This highlights the sense of urgency for the Philippines regarding the improvement of their MET to avoid future failure of international audits and ensure the global employment of Filipino seafarers.

[13] Maritime Industry Authority, supra note 10, at 112-120.

[14] Maritime Industry Authority, Philippines Re-elected to Council of IMO, available at https://marina.gov.ph/2019/11/30/philippines-re-elected-to-council-of-imo/ (last accessed February 2, 2023).

[15] Angelica Baylon & Vadm Santos, The Challenges in Philippine Maritime Education and Training, in International Journal of Innovative Interdisciplinary Research 34 (2011).

[16] Baylon & Santos, supra note 19,. at 39-41.

[17] Id.

[18] Cleto Del Rosario, et al., Improving Governance of Maritime Higher Education Institutions to Ensure Success of Filipino Cadets, in The Maritime Commons: Digital Repository of the World Maritime University 3301-3309 (2020).

[19] Id.

[20] Id.

[21] Phil Const. art 12, § 14

Article XIII Section 3 (protection of labor). This section states that "The State shall afford full protection to labor, local and overseas, organized and unorganized, and promote full employment and equality of employment opportunities for all."[22] This highlights the importance of improvement of the Philippines' MET programs. Despite recent developments, the Philippines may be blacklisted by the EMSA if standards are not met; thus, the country must constantly improve its Maritime program.

Article XIV Sections 1, 2(1), 4(1) (promoting the importance of education). SECTION 1. The State shall protect and promote the right of all citizens to quality education at all levels and shall appropriate steps to make such education accesible to all.[23]

SECTION 2. The State shall: (1) Establish, maintain, and support a complete, adequate, and integrated system of education relevant to the needs of the people and society.[24]

SECTION 3. The State recognizes the complementary roles of public and private institutions in the educational system and shall exercise reasonable supervisión and regulation of all educational institutions.[25]

The first and fourth sections of Article XIV show that quality education through recognized educational institutions is a must. It must be ensured that Philippine MET is constantly aligned with programs abroad. The second section's importance to this study stems from the fact that the Philippines is one of the world's leading suppliers of seafarers. Should the Philippines' supply of maritime workers be interrupted, its economy would likely face repercussions due to the Philippine maritime industry's contributions to the Philippine GDP.

Pertinent Treaties and Conventions. The 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

The Philippines has been a cooperative member of the IMO since 1964 as a signatory of the Convention of the Intergovernmental Maritime Consultative Organization, now called the IMO.[26] The IMO is the agency of the United Nations that oversees the maritime industry through global standard-setting authority for the safety, security, and environmental performance.[27] In 1978, the IMO held a convention to improve worldwide standards for the protection and training of professional mariners – the STCW Convention. As of 2018, 164 nations, representing 99.2% of world shipping tonnage, have ratified the STCW.[28]

The STCW has set down qualification standards for masters, officers, and watch personnel on seagoing merchant ships and has established standardized maritime training and certification across all IMO member states.[29] Since this study centers on MHEIs, along with the training and assessment carried out by MET Institutions, the STCW Convention will function as the appropriate framework to fully ensure the achievement of the globally defined objectives and standards of competence for maritime training.

2.1.2. Republic Acts.

Republic Act No. 10635. RA No. 10635 establishes the authority of the MARINA over the implementation of the aforementioned international convention of the STCW and other maritime laws.[30] Before this law, various functions, including issuing and canceling certificates of competency and proficiency, were delegated to different government agencies such as the PRC, TESDA, CHED, etc. Through this law, MARINA has effectively assumed these responsibilities as the sole overhead government authority towards developing the maritime industry and education in the Philippines and ensuring that the industry is compliant with international regulations.[31]

2.1.3. Charters of MARINA.

MARINA Citizen's Charter. This charter aims for a globally competitive Philippine maritime sector by leading a Progressive Maritime Administration for safer people, safer ships, and a cleaner marine environment.[32] Furthermore, it provides for issuing necessary permits to ensure ships' quality and Filipino seafarers' safety. This also includes licensing requirements of Filipino seafarers to ensure their service is in-line with the qualities set by the MARINA and other seafarer conventions. It provides for the different regulations, permits, and conventions that help make the Philippine Maritime Industry more competitive.

2.1.4. MARINA Memos and Circulars.

JCMMC No. 01, series of 2022. Joint CHED-MARINA Memorandum Circular (JCMMC) No. 01 series of 2022 elaborates on revised policies, standards, and guidelines (PSGs) for the program and course design of Bachelor of Science in Marine Transportation and Bachelor of Science in Marine Engineering programs.[33] MARINA has required MHEIs to ensure all practical assessments are based on the learning outcomes that students must learn. This elaborates on the standards for the performance indicators, metrics, targets, and curriculum.[34] It also requires MHEIs to include policies and procedures on the design, development, and monitoring of laboratory equipment

[22] Phil const. art 13, § 3
[23] Phil const. art 14, § 1
[24] Phil const. art 14, § 2(1)
[25] Phil const. art 14, § 4(1)
[26] Convention on the Intergovernmental Maritime Consultative Organization 1, opened for signature Mar. 6, 1948.
[27] International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, adopted July 7, 1978.
[28] Id.
[29] Id.
[30] An Act Establishing the Maritime Industry Authority (MARINA) as the Single Maritime Administration Responsible for the Implementation and Enforcement of the 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, as amended, and International Agreements or Covenants Related Thereto, Republic Act No. 10635, § 3 (2013).
[31] Id.
[32] Maritime Industry Authority, Citizen's Charter Handbook, available at https://marina.gov.ph/wp-content/uploads/2022/06/MARINA-CITIZENS-CHARTER-1ST-EDITION-2022.pdf (last accessed Feb. 25, 2023).
[33] Maritime Industry Authority, 2022 Philippine Response, available at https://marina.gov.ph/wp-content/uploads/2022/06/2022-PHILIPPINE-RESPONSE.pdf.
[34] Supra note 13, at 81.

and simulator exercises and ensure that the MHEIs systematically implement lessons aligned to the learning outcomes.

JCMMC No. 03, series of 2022. JCMMC No. 3 elaborates on the revised guidelines for MHEI program monitoring. CHED-MARINA has released the Outcomes Based Monitoring Instruments (OBMI) which will aid them in their Annual Monitoring Program. MHEIs will be under constant monitoring to ensure they adhere to the PSGs CHED-MARINA has established.[35] This monitoring includes the need for specific evidence for the inspector to verify the schools' compliance. This memorandum ensures the compliance of MHEIs' education programs to STCW standards. It emphasizes the regular monitoring that will be done to ensure continuous adherence and to analyze the state of MHEIs.

2.2. Management Frameworks.

2.2.1. Internal Factors Evaluation (IFE) Matrix.

Philippine MET IFE Matrix

Strengths	Weight	Score	Wtd. Score
Large manpower count of maritime workers			
Country location (i.e., archipelagic)			
Number of courses for maritime education			
Partnership between schools and shipping companies			
Passing rate of maritime education institutions			
Weaknesses	**Weight**	**Score**	**Wtd. Score**
Insufficient observation of safety protocols			
Poor student to faculty/personnel ratio			
Lack of necessary practical/laboratory equipment			
Inconsistent implementation of course materials			
Poor monitoring systems			
TOTAL			

2.2.2. Strengths.

The Philippines is one of the largest suppliers of seafarers, delivering 6.4 billion USD in revenues as of 2020, beating countries such as China and India.[36] The country is also archipelagic, which presents many opportunities for MET**.** Next, the large manpower count of seafarers is also brought about by the abundance of maritime schools in the Philippines, as there are 81 maritime schools in the country as of the year 2021.[37] Additionally, there are approximately 87,960 maritime students out of roughly 3.2 million enrollees for 2019-2020.[38] There are a total of 17,635 graduates from the maritime education discipline. Another strength is that some well-known shipping companies sponsor the maritime education of students in different universities that offer maritime education.[39]

2.2.3. Weaknesses.

Philippine MET's observation of safety protocols is insufficient, which resulted in the Philippines' continuous failure to comply with STCW requirements.[40] Delving deeper into the recent EMSA audit, the group has recognized other internal weaknesses such as poor monitoring systems, inconsistent course implementation, lack of equipment, and poor student-to-facilities/personnel ratios. Poor monitoring systems involve the absence of specific recording methods for data which include the students' attendance.[41] There also are inconsistencies with the course materials, specifically how the actual teaching of the course is executed compared to the course syllabi.[42] Another weakness is the lack of laboratory equipment that is necessary for the conduct of practical and laboratory assessments, as the poor ratio of students to laboratory equipment undermines the capability of students to operate these equipment.[43] Consequently, the weakness of a poor ratio is also observed between the student and the facility or personnel, which impacts the quality of learning.[44]

2.2.4. External Factors Evaluation (EFE) Matrix.

Philippine MET EFE Matrix

Opportunities	Weight	Score	Wtd. Score
Increasing global demand for filipino seafarers			
Proposal to increase MARINA's budget			
Implementing an improved maritime scholarship fund program			
Changes in the policies, standards, and guidelines (PSG) of CHED on maritime educational curriculum			
Maritime Exchange Student Programs			
Threats	**Weight**	**Score**	**Wtd. Score**
Future EMSA Audits			
Impact on the COVID-19 pandemic on learning			
CHED's immediate closing of MHEIs due to the deflection from the standard deviation of students to be accepted			
Emerging competitors in the seafarer market			
Expenses of maritime education			
TOTAL			

2.2.5. Opportunities.

Despite the increasing global supply of seafarers, the forecasted demand would exceed the supply in the future as the world merchant fleet is expected to grow over the next ten years.[45] This is an opportunity for Philippine MET to improve recruitment and training to meet global demands. Another opportunity is the proposal to increase MARINA's budget from P20.95 to P80.69 million in 2023.[46] Equipment for assessments and train-

[35] Id. at 91, 99.

[36] MI News Network, The Philippines Continues to be the Leading Provider of Seafarers and Officers, MARINE INSIGHT, November 24, 2021, available at https://www.marineinsight.com/shipping-news/philippines-continues-to-be-the-leading-provider-of-seafarers-and-officers/ (last accessed Feb. 25, 2023).

[37] Maritime Industry Authority, MARINA Statistical Report 2017-2021, at 2, available at https://marina.gov.ph/wp-content/uploads/2022/06/2017-2021-MARINA-Statistical-Report-1.pdf (last accessed Feb. 25, 2023).

[38] Jake M. Laguador, Maritime Students' Interest towards Enrolled College Degree and Experienced Program Difficulty, in ASIA PACIFIC JOURNAL OF MARITIME EDUCATION, 48.

[39] The Seafarer's Notebook, Maritime Programs and Scholarships in the Philippines, available at https://theseafarersnotebook.wordpress.com/2019/10/08/maritime-programs-and-scholarships-in-the-philippines/#:~:text=1 (last accessed Feb. 25, 2023).

[40] Karl Garcia, Some Observations on Philippine Maritime Education, The Maritime Review, November 26, 2021, available at https://maritimereview.ph/some-observations-on-philippine-maritime-education/ (last accessed Feb. 25, 2023).

[41] Maritime Industry Authority, Supra note 13, at

[42] Id. at 78

[43] Id. at 85

[44] Id. at 103

[45] International Chamber of Shipping, Shipping and World Trade: Global Supply and Demand for Seafarers, available at https://www.ics-shipping.org/shipping-fact/shipping-and-world-trade-global-supply-and-demand-for-seafarers/ (last accessed Feb. 26, 2023)

[46] Philstar.com, Budget Increase for Maritime Industry Authority's Law Enforcement Sought, available athttps://www.philstar.com/headlines/2022/11/17/2224509/budget-increase-maritime-industry-authoritys-law-enforcement-sought (last accessed Feb. 26, 2023)

ing would be improved through additional funding. Another opportunity is the maritime scholarship fund. PMMA, together with CHED, had created a P121.5 million scholarship fund that was intended to help finance instructors and students for further studies of maritime-related fields in the Philippines and abroad.[47] However, this failed as PMMA had poor planning and execution strategies and vague spending allocations. Nonetheless, this may be an opportunity for Philippine MET if improved. An effective maritime scholarship fund program would mean that instructors and students could further their studies and offer additional knowledge and suggestions on Philippine MET. CHED has vowed to improve its PSGs concerning the curriculum of maritime education.[48] This decision was made in light of the EMSA audit as CHED aims to promote quality education and training that align with global standards, proving the said factor to be an opportunity for the Philippine maritime industry. The Philippines conducted an exchange student program with maritime schools in Japan in 2018.[49] This program allowed Japanese and Filipino maritime students to learn from each other's environments, allowing MET to broaden their experiences.

2.2.6. Threats.

Future EMSA audits are a threat because if they find the Philippine MET even more insufficient, it will have to be further restructured, and the country may be placed in an even more precarious situation. This poses a threat since it could cause disruptions to the new policies and curriculum MARINA had imposed. The COVID-19 pandemic has also harmed maritime education with simulator activities and practical training shifted to digital learning. Due to this, the application and learning outcomes of these activities have not been fully realized.[50] With the issues laid down by the EMSA regarding Philippine MHEIs, CHED has tightened its grip on monitoring the schools' compliance with global maritime standards. As a member agency of MTC-DOLE, CHED took as its last recourse the closure of deficient maritime programs of maritime schools which, after having been given ample time and opportunity, still failed to rectify the deficiencies noted by CHED and EMSA.[51] Another threat would be the emerging competitors in the seafarer market who harbor more skilled workers due to their availability and sufficiency of educational and training mediums.[52] This would lead to a decline in the demand for Filipino seafarers, consequently affecting the country's economy. Lastly, considerable expenditures needed to sustain maritime education (e.g., facilities, equipment, tools) are among the pressures driving the need for CHED to increase standard maritime tuition fees.[53]

3. Chapter Three.

3.1. Data Gathering.

The researchers partnered with a Philippine MHEI to verify EMSA's audit and apply the legal and management frameworks. Most of the data collected is based on the interview with the institution's Vice-President. All specifics of the Partner institution and contact person shall be kept strictly confidential following the research ethics clearance.

3.2. Application of Legal Framework.

The legal framework will be contextualized in terms of whether the MHEI has taken the necessary steps to ensure compliance with the legal bases. Should a specific legal basis be deemed not directly concerned with the institution's practices, it will be contextualized in terms of its general impact.

3.2.1. 1987 Philippine Constitution.

Article XII Section 14 (sustained development of national talents)

Data indicates the partner institution's compliance with this particular section of the Constitution. To observe compliance with their carrying capacity, the school only permits 80 students to receive onboard training per semester for every student to access the necessary training equipment. It also observes a maximum ratio of 1 piece of equipment per 4 students. Moreover, to ensure that there is a constant presence of funds for equipment, it requests such on an incremental basis.

Article XIII Section 3 (protection of labor)

Data shows an attempt at compliance for this provision (i.e., revisions to the curriculum), albeit an insufficient one as the Philippines is still under the threat of being "blacklisted" by EMSA due to lack of compliance with global standards. This may be attributed to the schools' capacity building and HR Development for educational administrators and faculty members.

Article XIV Sections 1, 2(1), 4(1) (promoting the importance of education)

[47] Peter Tabingo, PMMA's P121M Maritime Scholarship Fund Fails to Sail, Malaya Business Insight, April 19, 2021, available at https://malaya.com.ph/news_news/pmmas-p121m-maritime-scholarship-fund-fails-to-sail/ (last accessed Feb. 26, 2023)

[48] Dan Navarro, CHED vows improved seafarer education, Daily Tribune, April 10, 2023, available at https://tribune.net.ph/2023/04/04/ched-vows-improved-seafarer-education/

[49] NYK Line, NYK Conducts Maritime Short-term Exchange Program for Students in Japan and the Philippines, available at https://www.nyk.com/english/news/2018/20181109_01.html (last accessed Feb. 26, 2023).

[50] Ergun Demirel, Impact of Covid 19 Pandemic on Maritime Education and Training, available at https://www.researchgate.net/publication/352836776_Impact_of_Covid_19_Pandemic_on_Maritime_Education_and_Training (last accessed Feb. 26, 2023).

[51] Department of Labor and Employment, On the Closure of Non-compliant Maritime Education Programs of the Philippine Maritime Institute, available at https://www.dole.gov.ph/news/on-the-closure-of-non-compliant-maritime-education-programs-of-the-philippine-maritime-institute/ (last accessed March 5,2023).

[52] Sarwell Meniano, Pinoy seamen need upskilling to adapt to emerging technologies, Philippine News Agency, Sept. 14, 2022, available at https://www.pna.gov.ph/articles/1183681

[53] Sunstar, Ched okays tuition, other fees hike in 56 private schools, Sunstar, Jan 12, 2022, available at https://www.sunstar.com.ph/article/1917901/manila/local-news/ched-okays-tuition-other-fees-hike-in-56-private-schools

Data indicates compliance for these articles. For Sections 1 and 4(1), the number of students enrolled in maritime institutions is strictly determined by their carrying capacity. For Section 2(1), compliance is observed through the teaching and learning methods shift. For the partner institution, a content-based teacher-centered approach was originally implemented – revolving around lectures and assessments. However, in 2017, a shift to an outcome-based learning approach was implemented which essentially "liberalizes" teaching methods and styles by setting goals and objectives for MET courses to achieve.

3.2.2. Pertinent Treaties and Conventions.

The 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

Data shows the MHEI's compliance with 1978 STCW Convention as it has implemented programs and standards that comply with its requirements in terms of the study's focus on the second key area. The partner MHEI ensures its facilities and equipment are sufficient to cater to the students' needs. It conducts practical laboratory and simulator exercises based on learning outcomes and incorporates theoretical subjects, allowing the institution to maximize its laboratory equipment. The MHEI has also based its course syllabi, course specifications, and learning outcomes on the standards for curriculum set by the STCW, with CHED's approval.

3.2.3. Republic Acts.

Republic Act No. 10635.

This law is concerned with establishing MARINA as the governing authority over maritime education and training, it does not directly impact the partner institution's compliance with the regulations imposed in the STCW, but its current influence is insufficient. MARINA's recent reforms aimed to address the lapses of the current industry; however, due to the agency's perceived non-effectiveness in education and curriculum development, maritime institutions are left to decide independently, causing significant discrepancies that the international audit has identified.

3.2.4. Charters of MARINA.

MARINA Citizen's Charter.

This charter mainly focuses on issuing permits, regulations, and conventions to make the industry more globally competitive. This does not directly affect the status of the compliance of the partner institution regarding the standards imposed by the STCW. Thus, the MARINA Citizen's Charter has no direct influence over the compliance of our partner institution.

3.2.5. MARINA Memos and Circulars.

JCMMC No. 01, series of 2022.

This memorandum tackles CHED-MARINA's revised policies, standards, and guidelines that MHEIs must follow regarding the practical assessments and learning outcomes. The partner institution has complied with these standards set by CHED-MARINA as the institution has also affirmed that their practical laboratory and simulator exercises are based on learning outcomes. They have also enhanced their curriculum according to CHED-MARINA's standards.

JCMMC No. 03, series of 2022.

As an MHEI, the partner institution is monitored under CHED - MARINA's Annual Monitoring Program. The school's education programs are compliant with STCW standards. Although no details were given regarding CHED-MARINA's monitoring program during the interview, it is cooperative in CHED-MARINA's monitoring efforts.

3.3. Application of Management Framework.

In the application of the following matrices, the institution's current strategies were assessed based on its capability to address the identified factors. Weight is determined based on the perceived impact of the factor to the performance of MET with the score being based on the following criteria:

Score	Criteria
4	Superior
3	Above Average
2	Average
1	Poor

The overall score can range from 1 (lowest) to 4 (highest), each score indicating the following:

IFE Matrix	
Total Score	**Criteria**
<2.5	Weak Internal Position
>2.5	Strong Internal Position

EFE Matrix	
Total Score	**Criteria**
<2.5	Institution's strategies do not take advantage of opportunities and defend well against threats.
>2.5	Institution's strategies adapt well to its environment.

3.3.1. Internal Factors Evaluation Matrix.

Philippine MET IFE Matrix			
Strengths	**Weight**	**Score**	**Wtd. Score**
Large manpower count of maritime workers	0.10	4	0.40
Country location (i.e., archipelagic)	0.10	4	0.40
Number of courses for maritime education	0.10	3	0.30
Partnership between schools and shipping companies	0.08	4	0.32
Passing rate of maritime education institutions	0.08	4	0.32
Weaknesses	**Weight**	**Score**	**Wtd. Score**
Insufficient observation of safety protocols	0.12	4	0.48
Poor student to facility / personnel ratio	0.12	4	0.48
Lack of necessary practical / laboratory equipment	0.12	4	0.48
Inconsistent implementation of course materials	0.10	2	0.20
Poor monitoring systems	0.08	3	0.24
TOTAL	1.00		3.58

3.3.2. Strengths.

Large manpower count of maritime workers (4).

This is due to the Philippines being one of the top sources for maritime workers which has been made possible due to the different maritime-related degree programs for those who are interested in pursuing a career in the maritime industry.

Country location (4).

As an archipelago, the Philippines possesses several bodies of water which allows for multiple locations for schools offering MET to conduct their training sessions. Moreover, it also allows for more MHEIs to open due to the vast number of marine resources available in the country.

Number of maritime education courses offered (3).

Currently, there are only 2 Maritime courses being offered by the partner institution: BS Marine Transportation and BS Marine Engineering. Originally, it offered 3 maritime courses, but has removed the third course due to sponsoring companies pulling out the job positions, specific to the course, from its roster.

Partnership between schools and shipping companies (4).

The partner institution is partnered with many shipping companies that provide OJT, on-board training, and scholarships to its students. Moreso, these partnerships and exposures may help the students in their employability following graduation.

Passing rate of maritime education institutions (4).

The partner institution continues to produce a large number of board passers from its maritime education programs. According to the interview data, it was claimed that the institution has a passing rate of 92%-93% for first-time takers.

3.3.3. Weaknesses.

Insufficient observation of safety protocols (4).

The issue of capacity building would result in the insufficient observation of safety protocols as there would be an unequal amount of safety training due to inconsistencies. Since EMSA's audit revolves around safety, this is an indicator of the overall Philippine MET's observation of safety protocols.

Poor student to facility/personnel ratio(4).

Despite its high number of enrollees, the partner institution strictly abides by its carrying capacity to ensure compliance with the STCW's requirement regarding the maximum number of students allowed. The institution accommodates around 1,700 students despite its computed maximum being around 1,800 students.

Lack of necessary practical/laboratory equipment (4).

The partner institution has shown that it is equipped with all the necessary equipment that is required under the STCW. They have been able to ensure that they maintain the 1:4 student-to-equipment ratio, with there being instances that more equipment is available for use than the minimum requirement, achieving a better 1:3 balance.

Inconsistent implementation of course materials (2).

Data shows a shift from a content-based approach to an outcome-based approach which allows for the unification of MET due to shared goals and objectives. However, the gaps in course material implementation are shown in its inconsistency as several MHEIs focus on standardized assessments such as midterm examinations. Moreover, there is no validation for learning outcomes as the faculty is given the liberty to teach their courses, resulting in teaching inconsistencies.

Poor monitoring systems (3).

There is sufficient but not entirely effective attendance monitoring in the institution. The current system relies on a manual tallying of attendance by the class secretary, which must be signed by the professor. However, the partner school has no mitigation mechanism in case of falsified attendance due to the manual nature of the system, of which the issue of falsified attendance has been found in other maritime institutions. The audit has noticed that some students pass the course even if their absences exceed the allowed 20% of the total required attendance.

3.3.4. Overall Score (3.58).

Considering how the institution's strategies are aligned to address these factors, the group has arrived at the above overall score. The score can be described as a sufficiently satisfactory performance from the institution, as it achieved a perfect score in nearly all stated factors. However, the most apparent weakness is the inconsistent implementation of course materials, providing the institution with a concrete indicator of the direction it must take for improvement.

3.4. External Factors Evaluation Matrix.

Philippine MET EFE Matrix

Opportunities	Weight	Score	Wtd. Score
Increasing global demand for Filipino seafarers	0.20	4	0.80
Proposal to increase MARINA's budget	0.15	2	0.30
Implementing an improved maritime scholarship fund program	0.10	1	0.10
Changes in the policies, standards, and guideline of CHED on maritime educational curriculum	0.05	3	0.15
Maritime Exchange Student Programs	0.05	4	0.20
Threats	**Weight**	**Score**	**Wtd. Score**
Future EMSA Audits	0.15	4	0.60
Impact of the COVID-19 pandemic on the economy	0.15	4	0.60
CHED's immediate closing of MHEIs due to the deflection from the standard deviation of students to be accepted	0.10	4	0.40
Emerging competitors in the seafarer market	0.10	3	0.30
Expenses of Maritime Education (facilities, equipment, tools, etc.)	0.05	2	0.10
TOTAL	1.00		3.55

3.4.1. Opportunities.

Increasing global demand for Filipino seafarers (4).

The partner institution is able to structure their strategies in order to meet this opportunity of increased demand. By adhering to CHED-MARINA guidelines and improving its curriculum, it can produce graduates who can meet this demand with their 100% employability rate.

Proposal to increase MARINA's budget (2).

The potential increase in MARINA's budget will be used for MARINA operations, so the target institution will not directly benefit. However, an increased budget would mean an improved state of Philippine MHEIs since MARINA would use the money to improve compliance with international standards. Since the target institution is an MHEI, they can improve operations through MARINA directives.

Implementing an improved maritime scholarship fund program (1).

The partner institution currently has no maritime scholarship fund program that's partnered with CHED. Previously, CHED had a maritime scholarship fund program in partnership with another MHEI, but none has been offered to them as the MHEI failed to respond to the scholarship opportunity with CHED.

Changes in the policies, standards, and guidelines (PSG) of CHED on maritime educational curriculum (3).

CHED's current PSG on maritime curriculum may not be outcome-based, but the partner MHEI was able to identify the need to incorporate the projected outcomes under each course syllabus. Instead of being heavily content-based, the MHEI shifted to an outcome-based curriculum by measuring the completion of each module not by time, but by the students' accomplishment of the outcome. It was able to recognize and apply the need for an outcome-based curriculum, however, it has yet to fully align itself with the changes in CHED's PSG.

Maritime Student Exchange Programs (4).

The partner institution was able to have its own student exchange program with other local and foreign universities. Both the students and faculty are presented the opportunity to be part of the exchange programs in order to encourage growth and learning through other institutions. In turn, this can positively affect the institution as their faculty and students gain more knowledge and expertise.

3.4.2. Threats.

Future EMSA Audits (4).

Recently, EMSA declared that the Philippines has adequately passed their audit.[54] Even though the EC will continue to recognize Filipino seafarers for now, there is the threat of the Philippines failing future EMSA audits if they do not consistently align themselves to international standards. However, the partner institution is taking measures to continue fixing their standards and curriculum. The institution is also continuously reviewing their policies in accordance with MARINA's directives in order to do their part in reforming the Philippine maritime education.

Impact of the COVID-19 pandemic on learning (4).

The abrupt shift from face-to-face to remote learning has affected the students' capacity to maximize the learning experience. However, the partner institution has now shifted to the face-to-face learning setup, allowing students to experience a richer understanding of practical training through physical simulation activities aligned with the courses' learning outcomes. Moreover, the pandemic currently does not affect the execution of its course plan and curriculum.

CHED's immediate closing of MHEIs due to the deflection from the standard deviation of students to be accepted (4).

Any violation to the magna carta that CHED has passed regarding the number of students that can be accepted is a threat as any violation of this would immediately result in the closing of the MHEI. Still, there is currently no violation of such by the partner MHEI.

Emerging competitors in the seafarer market (3).

With the emerging seafarer demand in countries such as Indonesia and China, the Philippines is faced with competitors that may make the country less appealing as a source of seafarers. This would threaten the partner institution as many of their graduates would have reduced employability after graduation. However, it has mentioned that its student graduates have a 100% employability rate due to their partnerships with shipping companies that would draft these students.

Expenses of Maritime Education (facilities, equipment, tools, etc.) (2).

The partner MHEI suggested that CHED raise the standard maritime tuition fees due to incurred expenses that have been deemed costly due to the number of facilities, equipment, tools, and faculty needed to operate maritime courses. Hence, this is a threat to the partner institution.

3.4.3. Overall Score (3.55)

The total EFE score is above average, indicating that the partner institution's strategies can meet opportunities and defend against threats. However, quite a number of factors were scored 1 or 2, indicating room for improvement. The maritime scholarship fund is one opportunity that is poorly taken advantage of by the institution, to which it needs to make changes to its strategies in order to address this opportunity.

[54] Cecille Felipe, Crisis averted: 50,000 Philippine seafarers keep jobs, The Philippine Star, Apr. 2, 2023, available at https://www.philstar.com/headlines/2023/04/02/2256259/crisis-averted-50000-philippine-seafarers-keep-jobs (last accessed Apr. 11, 2023).

4. Chapter Four.

4.1. Conclusion.

4.1.1. Common Insights Between Legal and Management Framework.

Through the legal and management frameworks, the partner institution has been evaluated regarding compliance with the legal bases and readiness to address various external and internal factors in its operations. Both frameworks indicate that it is *generally compliant* with most of the identified factors. In most legal bases, the researchers observed that the MHEI had achieved *sufficient compliance*, which translated into a satisfactory overall score in both the internal and external management frameworks. However, the score gap between the external and internal management frameworks indicates that while the institution has been performing adequately internally, its external environment has yet to be addressed equivalently. This observation is also evident in the legal framework, as the factors wherein the MHEI has been found to be insufficiently compliant have an external nature regarding cause and impact, hence, a clear alignment in both frameworks. Nonetheless, its consistency in finding strategies that adequately address the compliance issues may be interpreted as a strong commitment towards sustaining its good standing as a reputable Philippine MHEI.

4.1.2. Implications for the Target Institution and Industry.

The implication on the partner institution is their room for improvement. To ensure full compliance, the institution should address shortcomings regarding internal and external factors. To ensure sustainability, they must be more stringent in their policies, including improving their current policy of giving their faculty the liberty to teach their courses which creates teaching inconsistencies. Additionally, it needs strategies to defend against external threats, such as the rising expenses of facilities and equipment. This implies the need for the institution to be more active in finding ways to combat threats and weaknesses that could affect its state. Implementing such changes would allow for sustainable operations that would benefit the institution and the industry.

Concerning the Philippine Maritime Industry, the institution's deficiency regarding external factors indicates its lack of competitiveness with global standards. Despite the EC's recent move to continue recognizing Filipino seafarer certificates, its intention to provide technical assistance to the Philippines indicates the presence of deficiencies. As one of the leading providers of maritime employees internationally, these inconsistencies could bring negative long-term implications to the industry. The lack of a scholarship fund program would prevent those who lack funds but are otherwise skilled from pursuing MET, which may subsequently impact the quality of the supply of Filipino seafarers domestically and internationally. Additionally, given the high expenses of the industry, the low budget allocated to the sector also prevents the further improvement of MET. If these external factors continue to be unresolved, this could potentially result in the Philippines being "blacklisted" in the future, which would severely impact the Philippine economy.

4.2. Recommendations.

4.2.1. The Institution.

A recommendation for the institution would be to reinstate its BS in Marine Engineering and Electro-technology (BS MEET) program. The institution previously mentioned reducing the number of maritime-related programs offered in their institution due to a partner company closing applications for the electro-engineer position. Reintroducing the program could present them with an opportunity to partner up with other companies in need of the services that require BS MEET qualifications. This helps the institution increase their student intake and the overall number of Philippine seafarers.

4.2.2. The Industry.

With the significant contribution of Filipino seafarers to the country's economy, the Philippine maritime industry must ensure its compliance with the 1978 STCW Convention, Republic Acts, and MARINA memos and circulars, including its ability to adapt to internal and external trends such as technological advancements in education and increasing maritime education expenses.[55] MARINA's audit on the country's maritime industry yielded results that pointed to a deficiency in the quality and effectiveness of Philippine MET, hence, the industry must be reformed through a development and expansion plan that covers the enhancement of safety and security training programs, digitalization and modernization of learning, and adoption of an effective and efficient maritime administration governance system.

4.2.3. Future Researchers.

With the continued growth of the maritime industry, further studies must be conducted to juxtapose current maritime programs with global standards. The findings and recommendations of this paper may not apply to the future of maritime, hence the need to stay up to date with the new changes in maritime global standards and industry. As only the second key area of the EMSA audit was tackled, it is best for future researchers to include all six key areas to provide a better overview of the sustainability and global competitiveness of the Philippine maritime industry.

References.

Primary Sources.

CONSTITUTIONS.

THE 1987 CONSTITUTION OF THE REPUBLIC OF THE PHILIPPINES.

TREATIES AND CONVENTIONS.

Convention on the Intergovernmental Maritime Consultative Organization 1, *opened for signature* Mar. 6, 1948.

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, *adopted* July 7, 1978.

[55] Helen Flores,Time to prioritize maritime industry, The Philippine Star, March 1, 2023, available at https://www.philstar.com/headlines/2023/03/01/2248441/time-prioritize-maritime-industry (last accessed March 31, 2023).

CODES AND STATUTES.

An Act Establishing the Maritime Industry Authority (MARINA) as the Single Maritime Administration Responsible for the Implementation and Enforcement of the 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, as amended, and International Agreements or Covenants Related Thereto, Republic Act No. 10635, (2013).

Secondary Sources.

JOURNALS AND LEGAL ARTICLES.

Baylon, A. & Santos, V. "The Challenges in Philippine Maritime Education and Training", International Journal of Innovative Interdisciplinary Research (2011).

Del Rosario, C. et al., "Improving Governance of Maritime Higher Education Institutions to Ensure Success of Filipino Cadets", The Maritime Commons: Digital Repository of the World Maritime University (2020).

Laguador, J.M. "Maritime Students' Interest towards Enrolled College Degree and Experienced Program Difficulty", ASIA PACIFIC JOURNAL OF MARITIME EDUCATION (2019).

Mendoza, V.M., "Filipino Maritime Students and Seafarers: Defying Dominant Social Imaginaries", PHILIPPINE SOCIOLOGICAL REVIEW (2015).

Ochavillo, G.S., "A Paradigm Shift of Learning in Maritime Education amidst COVID-19 Pandemic", INTERNATIONAL JOURNAL OF HIGHER EDUCATION (2020).

MAGAZINE AND NEWSPAPER ARTICLES.

Flores, H., *Time to prioritize maritime industry,* The Philippine Star, March 1, 2023, *available at* https://www.philstar.com/-headlines/2023/03/01/2248441/time-prioritize-maritime-industry (last accessed March 31, 2023).

Garcia, K., *Some Observations on Philippine Maritime Education,* The Maritime Review, November 26, 2021, *available at* https://maritimereview.ph/some-observations-on-philippine-maritime-education/

MI News Network, *The Philippines Continues to be the Leading Provider of Seafarers and Officers*, Marine Insight, November 24, 2021, *available at* https://www.marineinsight.-com/shipping-news/philippines-continues-to-be-the-leading-provider-of-seafarers-and-officers/

Philstar.com, *Budget Increase for Maritime Industry Authority's Law Enforcement Sought*, PHILSTAR, November 17, 2022, *available at*https://www.philstar.com/headlines/2022/11/-17/2224509/budget-increase-maritime-industry-authoritys-law-enforcement-sought

Philstar Global, *Philippines Corrects Course to Meet Global Seafarer Training Standards,* Philstar, November 17, 2022, *available at* https://www.philstar.com/headlines/2022/11/17/2224535/-philippines-corrects-course-meet-seafarer-training-standards

Tabingo, P., *PMMA's P121M Maritime Scholarship Fund Fails to Sail,* Malaya Business Insight, April 19, 2021, *available at* https://malaya.com.ph/news_news/pmmas-p121m-maritime-scholarship-fund-fails-to-sail/ (last accessed February 26, 2023)

Dan Navarro, *CHED vows improved seafarer education,* Daily Tribune, April 10, 2023, *available at* https://tribune.net.ph-/2023/04/04/ched-vows-improved-seafarer-education/

Sarwell Meniano, *Pinoy seamen need upskilling to adapt to emerging technologies,* Philippine News Agency, Sept. 14, 2022, *available at* https://www.pna.gov.ph/articles/1183681

Sunstar, *Ched okays tuition, other fees hike in 56 private schools,* Sunstar, Jan 12, 2022, *available at* https://www.sunstar.-com.ph/article/1917901/manila/local-news/ched-okays-tuition--other-fees-hike-in-56-private-schools

Cecille Felipe, *Crisis averted: 50,000 Philippine seafarers keep jobs,* The Philippine Star, Apr. 2, 2023, *available at* https://www.philstar.com/headlines/2023/04/02/2256259/crisis-averted-50000-philippine-seafarers-keep-jobs (last accessed Apr. 11, 2023).

INTERNET SOURCES.

Demirel E., Impact of Covid 19 Pandemic on Maritime Education and Training, *available at* https://www.researchgate.net/-publication/352836776_Impact_of_Covid_19_Pandemic_on_Maritime_Education_and_Training.

International Chamber of Shipping, Shipping and World Trade: Global Supply and Demand for Seafarers, *available at* https://www.-ics-shipping.org/shipping-fact/shipping-and-world-trade-global-supply-and-demand-for-seafarers/

Maritime Industry Authority, 2022 Philippine Response, *available at* https://marina.gov.ph/wp-content/uploads/2022/06/2022-PHILIPPINE-RESPONSE.pdf

Maritime Industry Authority, Citizen's Charter Handbook, *available at* https://marina.gov.ph/wp-content/uploads/2022/06/-MARINA-CITIZENS-CHARTER-1ST-EDITION-2022.pd

Maritime Industry Authority, MARINA Statistical Report 2017-2021, *available at* https://marina.gov.ph/wp-content/uploads-/2022/06/2017-2021-MARINA-Statistical-Report-1.pdf

NYK Line, NYK Conducts Maritime Short-term Exchange Program for Students in Japan and the Philippines, *available at* https://www.nyk.com/english/news/2018/20181109_01.html

Organisation for Economic Co-operation and Development, Ocean Shipping and Ship Building, *available at* https://www.oecd-.org/ocean/topics/ocean-shipping/

Oxford Business Group, Filipinos are Active in the Global Maritime Sector, *available at* https://oxfordbusinessgroup.com/reports/philippines/2015-report/economy/seafaring-nation-filipino-workers-have-become-an-essential-part-of-the-global-maritime-industry

Technical Education and Skills Development Authority, The Philippine Maritime Industry Through the Years, at 12, *available at* https://www.tesda.gov.ph/Uploads/File/planning2017/-LMIR/MARITIME%20LMIR%20March%2017%20with%20-cover%202017.pdf

The Seafarer's Notebook, Maritime Programs and Scholarships in the Philippines, *available at* https://theseafarersnotebook.-wordpress.com/2019/10/08/maritime-programs-and-scholarships-in-the-philippines/#:~:text=1

United Nations Economic and Social Commission for Asia and the Pacific, The Philippine Maritime Industry: Prospects

and Challenges in 2013 and Beyond, at 1, *available at* https://-www.unescap.org/sites/default/files/0.Philippines-1.pdf

Department of Labor and Employment, On the Closure of Non-compliant Maritime Education Programs of the Philippine Maritime Institute, *available at* https://www.dole.gov.ph/news/-on-the-closure-of-non-compliant-maritime-education-programs-of-the-philippine-maritime-institute/ (last accessed March 5,2023).

Maritime Industry Authority, Philippines Re-elected to Council of IMO, *available at* https://marina.gov.ph/2019/11/30/philippines-re-elected-to-council-of-imo/ (last accessed February 2, 2023).

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 46–50

ISSN: 1697-4840, www.jmr.unican.es

Numerical Estimation and Validation of Drag Force for KCS Hull using STAR CCM+

Obaid Ullah Khan[1], Zeeshan Riaz[1], Asif Mansoor[1], Behzad Ahmed Zai[1], Najam us Saqib[2,*]

ARTICLE INFO

Article history:
Received 30 Apr 2023;
in revised from 28 Jun 2023;
accepted 28 Aug 2023.

Keywords:
CFD, STARCCM+, Resistance, Ship, RANS, DFBI.

ABSTRACT

Resistance prediction is mandatory for the optimal ship design and propulsion power requirement. This paper presents the resistance prediction of a container ship model, SVA KCS in calm water using Computational Fluid Dynamics (CFD) commercial software STARCCM+. It uses Reynolds Navier stokes equation for solving the numerical model. The numerical results of the KCS hull in calm water with the available experimental results are compared. A virtual towing tank experiment allowing all 3 DOF (heave pitch and surge) with the propeller propelling behind the ship at self-propulsion point is conducted. The result includes total drag force (shear & pressure), average sinkage and trim data. Rendered free surface visualization, pressure distribution and wake pattern has also been included. Furthermore, EHP (Estimated Hull performance) module of STARCCM+ has been used to predict the resistance of same hull. The obtained results demonstrate that the commercial CFD software STARCCM+ has the capability to predict the resistance, sinkage and trim of a ship hull. Subsequently, using EHP, automated module setup time and errors are greatly reduced.

1. Introduction.

Ship resistance predication is of much importance in the initial stage of ship design, although towing test experiments are commonly used to estimate the resistance of new hull. Furthermore, model tests take a lot of time and there is much possibility of error in constructing that model and placing the appendages at the right places. Towing tank tests with the propeller behind the ship predicts the flow field much better than the unappended towed hull. Self-propulsion tests are needed to be carried out to predict the self-propulsion point of ship. These towing tank experiments are very costly and the demand of solving this numerically has been increased enormously. CFD has gained much popularity for the prediction of resistance and other maneuverability characteristics due to its accuracy and economics. The computational time and cost for fully resolving the flow around a propeller is immensely high compared to Body force propeller method[1]. Studies showed that comparing the fully resolved propeller method and the body force method showed a good agreement for the predicated total force [2–3]. Benchmarking of the validation of Experimental and computational results are carried out in SIMMAN[4–5] Workshop for the resistance and maneuvering characteristics prediction. Three test models are selected for the benchmarking i.e. KCS, KVCC-L2 and DTMB 5415.

Simcenter STARCCM+ is used for numerically solving the resistance prediction. it has greatly advanced in marine industry for its easy process automation, various wave model from flat wave to 5th order wave, dynamic fluid body interaction (DFBI) for capturing different types of ship motions and high resolution interface capturing scheme has made this software most favorable for solving numerical grids of Ships. Simcenter STARCCM+ also comes up with an estimated hull performance module (EHP) which enables the users to setup marine simulation in few clicks, consequently, saving a lot of setup time. This paper

[1]Department of Engineering Sciences, PN Engineering College, National University of Sciences and Technology (NUST), Karachi, Pakistan.

[2]Department of Mechanical Engineering, NED University, Karachi, Pakistan.

[*]Corresponding author: Najam us Saqib. E-mail Address: najamussaqib1987@gmail.com.

presents the virtual towing test of ships for resistance prediction using STARCCM+.

2. Model.

Resistance prediction is performed on a scaled KCS ship. This ship is especially designed for the verification and validation purpose and its model data and experimental results are available worldwide. These validations and experimental testing has been a part of different workshops like SIMMAN and Tokyo. Model ship data along with the hull files are obtained from SIMMAN [3]. Fig 1 shows the isometric view of the KCS Hull and the principal parameters of KCS are given in Table 1.

Figure 1: KCS Hull Isometric View.

Source: Authors.

Table 1: Dimensional Parameters of KCS Hull.

Component	Main Variables	Full scale	Model scale	Unit
Hull	Length between perpendiculars (Lpp)	230	4.3671	m
	Load waterline length (Lwl)	232.5	4.4141	m
	Beam waterline length (Bwl)	32.2	0.6114	m
	Depth (D)	19	0.450	m
	Draught (T)	10.8	0.2051	m
	Displacement (∇)	52030	0.3562	m^3
	Surface w/o rudder (S)	9530	3.4357	m^2
	Block coefficient (CB)	0.651	0.651	-
	Midship coefficient (CM)	0.985	0.984	-
Rudder	Surface area of rudder	115	0.0415	m^2
	Lateral Area of rudder	54.45	0.0196	m^2
	Turn rate	2.32	16.8	Deg/s
Propeller	No of blades	05	05	-
	Diameter (D)	7.9	0.150	m
	Rotation	Right handed	Right handed	-
	Hub ratio	0.180	0.227	-
	P/D	0.997	1.30	-

Source: Authors.

3. Numerical Modelling.

Mesh motion technique with rigid mesh motion model i.e. DFBI Rotation and Translation is applied to the computational domain. This technique updates the position of computational domain as the solver runs. It uses RANS formulation along with the continuity and momentum equation with a modification in the conservation equations for the mesh motion. VOF multiphase model is used with the High Resolution Interface Capturing scheme (HRIC) to capture the sharp interfaces of immiscible fluids (air and water). K-ε Turbulence model with all y+ layers treatment is used to capture the turbulence, the K-ε model has been extensively used in predicting the hydrodynamic performance of the ship and it is quite economical in simulation time compared with the k-w turbulence model [6]. Segregated flow solver is selected to solve the integral conservation of equation of mass and momentum.

Hexahedral mesh is used for the domain with volume refinements to capture the wake and accurate prediction of resistance. Mesh and time step sensitivity study is conducted using three different mesh sizes and the time step. Mesh sensitivity is conducted using the finest time step and time step sensitivity using the optimum mesh size, the details are shown in the Table 2 and Table 3. The connective time scale is the ration of LOA and Hull velocity. Final mesh size of 1.5M is selected to compare results with Experimental data which shows the details of mesh at different sections as shown in Fig 2.

Table 2: Total Resistance for different mesh cases.

Mesh Elements (M)	Drag (N)	Simulation Time (Hrs)	% Difference
0.6	20.35	5.13	-
1.5	20.32	13	0.63
2.5	20.31	23	0.049

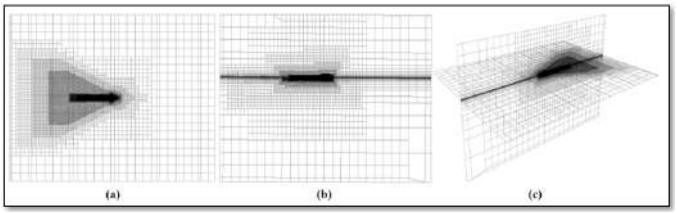
Source: Authors.

Table 3: Total Resistance for different time steps.

Time Step size	Drag (N)	Simulation Time (Hrs)	% Difference
Convective time scale/50	20.38	7	-
Convective time scale/100	20.33	13	0.24
Convective timescale/200	20.32	26	0.049

Source: Authors.

Figure 2: (a) Top view of the mesh showing wake region, (b) Side view of mesh showing the free surface, (c) Isometric view showing the mesh of whole domain.

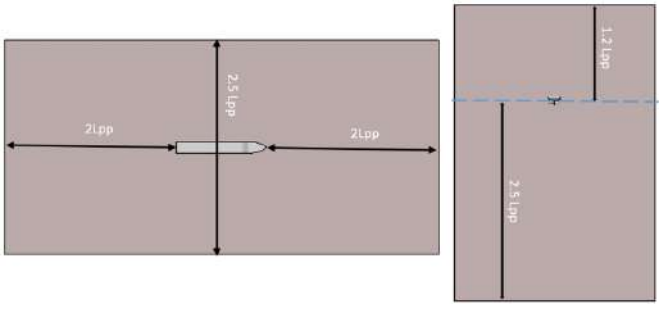


Source: Authors.

4. Computational domain and boundary condition.

The computational domain is made according to the ITTC standards[7] as shown in Fig. 3. The domain is made with a distance of 2Lpp in front and behind of the ship, 1.2Lpp above the free surface and 2.5Lpp below the free surface and 2.5Lpp in the lateral direction. Another setup with computational domain made automatically using the EHP module is also analyzed. Standard boundary conditions are applied using Simcenter STARCCM+ help files for calm water resistance predictions, the inlet, sides and top are treated as velocity inlet and the outlet is treated as the pressure outlet with a hydrostatic wave pressure specification. The ship boundary is treated as a no slip wall. Propeller is modelled using the body force propeller method, the advance coefficient, torque coefficient and the efficiency values are obtained from the SIMMAN 2008 website for KCS with propeller operating at the ship propulsion point i.e. 14rps [3]. The ship is free to move in 3DOF (two translations and one rotation) i.e. surge, heave and pitch and is constraint in the other 3DOF, these conditions are taken from the towing tank test [8] and replicated accordingly.

Figure 3: Computational Domain of KCS Hull.

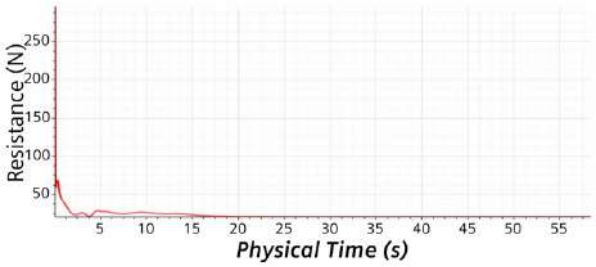


Source: Authors.

4.1. Results and discussion.

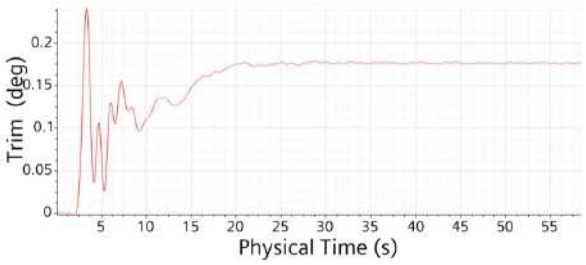
A ship moving in calm water experiences a force in the opposite direction of motion, this force is called the total resistance (R_T). This resistance is composed of mainly two components i.e. the Frictional resistance and the Pressure resistance. Friction of the water acting over the wetted surface area causes a force acting tangentially to the ship in the opposite direction of motion. This frictional force depends upon the surface roughness, viscosity and wetted surface area. In this study, surface roughness has not been taken into account. Pressure resistance is composed of the viscous wave making resistances. Simulation is performed on the optimum time step and the mesh size, convergence for resistance, sinkage and trim is obtained. An asymptotic convergence criterion of 0.0001 is selected for all three measured characteristics as shown in Fig 4-Fig 6.

Figure 4: Resistance Convergence.



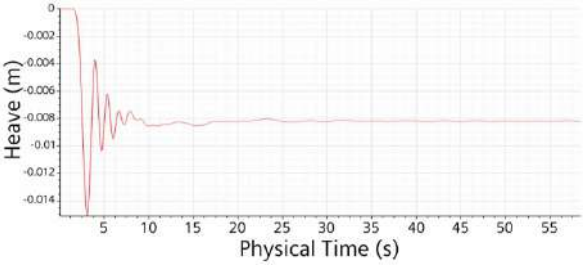
Source: Author.

Figure 5: Trim convergence.



Source: Author.

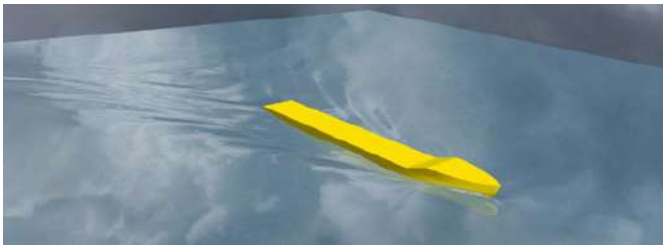
Figure 6: Heave convergence.



Source: Author.

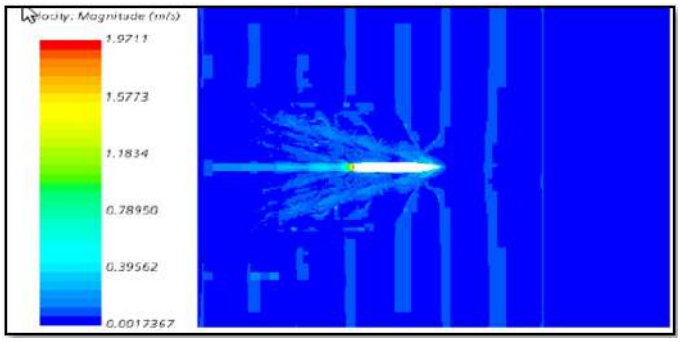
A Kelvin wake pattern has been formed behind the ship depicting the accuracy of the simulation, the free surface elevation has been captured with HRIC model. Fig 7 - Fig 8 show the wake field contours and the rendered view of the wake in water. Fig 9 shows the pressure distribution of the hull indicating higher pressure on underwater hull and Fig 10 and Fig 11 show the captured free surface and its elevation.

Figure 7: Rendered Kelvin Wake Pattern.



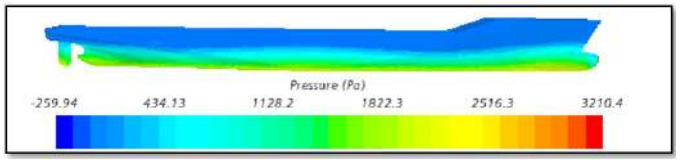
Source: Author.

Figure 8: Kelvin wake pattern velocity contours.



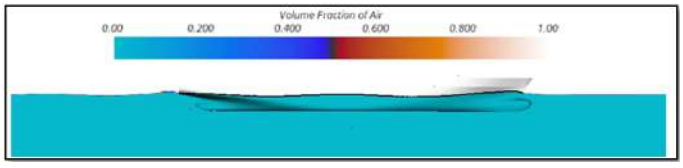
Source: Author.

Figure 9: Pressure Distribution around hull.



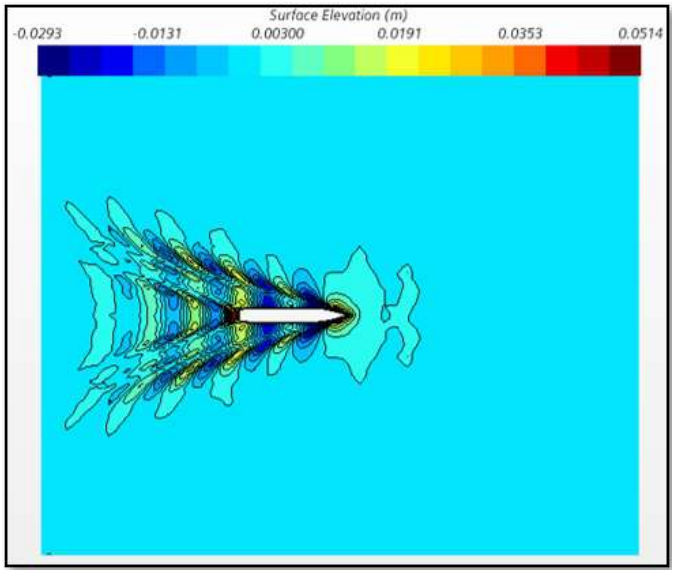
Source: Author.

Figure 10: Captured Free surface.



Source: Author.

Figure 11: Free surface Elevation.



Source: Author.

The resistance coefficient, sinkage and trim are shown in Eq. (1) to Eq. (8):

$$C_T = \frac{X}{1/2\rho S V^2} \tag{1}$$

$$C_F = \frac{0.075}{(log_{10}Re - 2)^2} \tag{2}$$

$$C_R = C_T - C_F \tag{3}$$

$$\frac{\sigma}{L_{PP}} = \frac{\Delta FP + \Delta AP}{L_{PP}} \tag{4}$$

$$\tau = \frac{(\Delta FP - \Delta AP)}{L_{PP}} \tag{5}$$

Where,

X is the total resistance

S is the wetted surface

ρ is the density of water

The total resistance coefficient, and the residuary resistance coefficient are calculated using the Eq. (1) to Eq. (5) and compared with the experimental values. The experimental results for this configuration of KCS model ship is only available for Froude number 0.26, the comparison of CFD and EFD results are tabulated in Table 4.

Table 4: Comparison between CFD and EFD Results.

Variables	Experimental values	Simulated results	% Difference
CT	$4.31*10^{-3}$	$4.106*10^{-3}$	4.71%
CR	$1.07*10^{-3}$	$1.0*10^{-3}$	6.54%
Heave (m)	0.2100	0.21319	1.43%
Trim (Deg)	0.185	0.176	4.86%

Source: Authors.

Conclusions

This paper shows the simulation of scaled model of KCS Hull. Virtual towing tank task has been performed for calculating the resistance, average sinkage and trim values. The method presented above using the mesh motion technique with dynamic fluid body interaction gives the ability to apply real life boundary conditions and constraints. The EHP modules offers quick setup from geometry to solution and post processing in just few clicks, it is designed to be used by non-expert users as well as experienced engineers. This paper recommends the use of EHP module of STARCCM+ for Virtual towing test simulations. The Experimental and the simulated results shows a good comparison. Overall it can be concluded that the STARCCM+ mesh motion technique can be adopted for performing fast virtual towing tests.

References.

[1] Yao.J.X. (2015). On the propeller effect when predicting hydrodynamic forces for maneuvering using RANS simulation of Captive model tests. Retrieved from DOI: 10.14279/depositonce-4682.

[2] Zipfel,J.S.,Wagner, S., & Abdel Maksoud, M. (2014-December) RANS Simulation of hydrodynamic forces acting on KVCCL2 tanker. Proceedings of workshop on verification and validation of ship maneuvering simulation methods, Copenhagen, Denmark..

[3] SIMMAN. (2008). Workshop on verification and validation of ship maneuvering simulation methods, Copenhagen, Denmark. Retrieved from http://www.simman2008.dk/.

[4] SIMMAN. (2014). Workshop on verification and validation of ship maneuvering simulation methods, Copenhagen, Denmark. Retrieved from http://www.simman2014.dk/.

[5] Quérard, A., Temarel, P., & Turnock, S. (2008, January). Influence of viscous effects on the hydrodynamics of ship-like sections undergoing symmetric and anti-symmetric motions, using RANS. Proceedings of the 27th International Conference on Offshore Mechanics and Arctic Engineering, Estoril, Portugal.

[6] Yi Liu, Lu Zou, Zaojian Zou & Haipeng Guo (2018) Predictions of ship maneuverability based on virtual captive model tests, Engineering Applications of Computational Fluid Mechanics, 12:1, 334-353, DOI: 10.1080/19942060.2018.1439-773.

[7] ITTC. (2011). Guideline on used of RANS tools for maneuvering prediction (No. 7.5-03-04-01). Retrieved from website: https://ittc.info/media/4204/75-03-04-01.pdf.

[8] Numerical Ship Hydrodynamics: An Assessment of the Tokyo 2015 Workshop (2015) Retrieved from. http://www.t2015-.nmri.go.jp/.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 51–57

ISSN: 1697-4840, www.jmr.unican.es

Investing in Seafarer Mental Health: A Financial Analysis in India and Vietnam

Le Thi Minh Que[1], C. Vairavan[2,*]

ARTICLE INFO

Article history:
Received 3 May 2023;
in revised from 28 Jun 2023;
accepted 28 Aug 2023.

Keywords:
seafarers, mental health, shipping industry, India, Vietnam, financial analysis.

ABSTRACT

The shipping industry plays a vital role in the global economy and employs an estimated 1.5 million seafarers worldwide. However, working at sea can be challenging and stressful, leading to mental health issues such as depression, anxiety, and suicide. This paper provides a financial analysis of investing in seafarer mental health in India and Vietnam, two significant contributors to the seafaring workforce. It discusses the challenges faced by seafarers, the impact of mental health on the industry, and the costs and benefits of investing in seafarer mental health. By analyzing existing mental health programs in India and Vietnam. The article highlight the importance of prioritizing seafarer mental health and provide insights for policymakers and industry stakeholders.

1. Introduction.

According to the World Health Organisation, depression affects 264 million people worldwide and describes that "the burden of mental disorders continues to grow with significant impacts on health and major social, human rights and economic consequences in all countries of the world" (WHO)[1]. The Mission to Seafarers' primary area of focus is the mental health issues that seafarers encounter while aboard ships. Seafarers' working conditions, lengthy shifts, financial concerns, and even the loneliness brought on by spending so much time away from home and friends can all contribute to seafarers' mental health problems. Given the sacrifices that seafarers make to maintain the health and wellbeing of our global economy, it is our opinion that it is only reasonable to offer them as much help as we can. Everyone among the seafarers must be prepared to provide assistance and support when it is most needed since, seafarers are vitally important employees who frequently go unappreciated for their efforts. The article has shown that seafarers are at increased risk of developing mental health issues such as depression, anxiety, and suicide. According to a study conducted by Bohlken, J, Schömig, F., Lemke, M. R., & Pumberger, M (2019), seafarers have higher rates of depression and anxiety than the general population, with an estimated 25% of seafarers experiencing mental health problems. Furthermore, the COVID-19 pandemic has exacerbated the already challenging conditions for seafarers, leading to increased stress and mental health issues[2].

1.1. Importance of investing in seafarer mental health.

Investing in seafarer mental health is essential for the wellbeing of seafarers and the safety of the maritime industry. Poor mental health among seafarers can lead to increased accidents, lower job performance, and even suicide, as noted by a study conducted by the International Transport Workers' Federation (ITF) (2021)[3]. Additionally, seafarers' mental health is critical for the long-term sustainability of the shipping industry. Investing in seafarer mental health can lead to better retention rates and reduced recruitment costs, as noted by a study conducted by the International Maritime Organization (IMO) (2019)[4]. As such, it is worth noting that seafarers' mental health has been

[1]Senior Lecturer, Banking Academy, No.12 Chua Boc str., Dong Da dis., Hanoi, Vietnam.

[2]Assistant Professor, Department of English, Academy of Maritime Education and Training Deemed to be University, Kanathur, Chennai.

[*]Corresponding author: C. Vairavan. E-mail Address: vairavaneng@gmail.com.

a long-standing issue in the maritime industry, and investing in seafarer mental health is not only a matter of ensuring the safety and well-being of seafarers but is also critical for the sustainability of the shipping industry in the long run.

Therefore, this study aims to shed light on the urgency of addressing this issue by examining the challenges faced by the shipping industry in India and Vietnam and highlighting the potential for positive financial returns from investing in seafarer mental health. Furthermore, we will also examine the costs and benefits of investing in seafarer mental health and provide a case study of existing mental health programs in India and Vietnam. By analyzing the financial aspects of investing in seafarer mental health, this paper highlights the importance of prioritizing seafarer mental health and provide insights for policymakers and industry stakeholders.

2. Methods.

On February 2, 2023, studies were looked up on Science Direct, Google Scholar, International Maritime Organization, Government of India Ministry Shipping, World Health Organization, MEDLINE/PubMed, SCOPUS, EMBASE, Academic Search Complete using EBSCO host databases, and Web of Science. Studies that established the association between variables related to working conditions met the inclusion criteria.

3. Overview of the Shipping Industry in India and Vietnam.

India's shipping industry shows that higher numbers of seafarers appear to suffer from depression than other working groups and that determinants of mental health disorders among seafarers include work environmental factors, job satisfaction, and self-rated health. [5 & 6] Well documented connectivity issues at sea and working far from home can mean that access to support and confidential health care can be a major challenge to seafarers. Vietnam shipping industry has provided "the mental healthcare industry in Vietnam is still developing. The government has established the National Mental Health Programme (NMHP); however, industry observers have noted that the NMHP only covers approximately 30 percent of the country, and uses a very narrow list of mental illness. While the government estimates that approximately 15 percent of the population requires mental health care services, independent research suggests that the figure is closer to 20 to 30 percent of the population"[7]. When mental illnesses are associated with shame and dishonour in a society, it can make it difficult for people to talk openly about their suffering. Since it needs accommodating a niche market on the one hand and operating in a low-cost environment on the other, building a mental healthcare industry may not immediately appeal to foreign investors. However, the demographic dividend of the nation is partly responsible for its swift economic expansion, and there is a rising need for all types of medical care, including mental health treatments.

3.1. Importance of the shipping industry in India and Vietnam.

[8]The Government of India Ministry Shipping states that "the Indian shipping industry also plays an important role in the energy security of the country, as energy resources, such as coal, crude oil and natural gas are mainly transported by ships. Further, during crisis situation, Indian shipping contributes to the uninterrupted supply of essentials, and can serve as second line of defence. Approximately, 95% of the country's trade by volume and 68% interms of value, is being transported by sea". India and Vietnam are two of the world's largest seafaring nations, with a combined seafaring workforce of over 4,50,000 people. The shipping industry plays a crucial role in the economies of both countries, with India's shipping industry accounting for 95% of the country's trade by volume and Vietnam's shipping industry accounting for 90% of its trade by volume. [9]Maritime Transport describes that the world seaborne trade (2021) having contracted by nearly four per cent in 2020 on the back of the COVID-19 pandemic, international maritime trade recovered in 2021 as volumes bounced back at an estimated rate of 3.2 per cent. Shipments reached 11.0 billion tons, a value slightly below pre-pandemic levels.

[9]In 2021, Asia remained the world-leading maritime freight area with Asian ports, including in developed and developing regions, loading around 4.6 billion tons of goods, or about 42 per cent of total goods loaded in ports worldwide. About 7.1 billion tons, equivalent to 64 per cent of total goods discharged worldwide, were received by Asian ports in 2021. A key trend in maritime trade is the shift in cargo composition. In 1970, more than half of global seaborne trade was tanker cargo. Today, almost three-quarters of loaded goods are dry cargo, including bulk and cargo shipped in containers. Of the total maritime freight shipped internationally in 2021, 8.0 billion tons was dry cargo. Vietnam's maritime trade has been largely driven by exports, which accounted for 90% of the country's seaborne trade in 2021. The value of Vietnam's seaborne trade in 2021 was estimated at $538 billion, a 24% increase from the previous year. Furthermore, the shipping industry in both countries provides significant employment opportunities, particularly in coastal regions.

3.2. Key players in the shipping industry in India and Vietnam.

The shipping industry in India and Vietnam is dominated by a few key players. In India, the state-owned Shipping Corporation of India (SCI) is the largest player in the shipping industry, with a fleet of over 60 vessels. Private players such as Adani Ports and Special Economic Zone and Essar Ports have also emerged as significant players in the industry, with Adani Ports handling a total cargo volume of 247 million tonnes in the fiscal year 2021-22.

Similarly, Vietnam's shipping industry has also experienced significant growth in recent years, with the country's seaports handling a total cargo volume of 803 million tonnes in 2021. The state-owned [7]Vietnam National Shipping Lines (Vinalines) is the largest player in the industry, with a fleet of over 80 vessels. Private players such as Saigon Newport Corporation and Vung Tau Bien Dong Port also have a significant presence in

the industry, with Saigon Newport Corporation handling a total container volume of 6.6 million twenty-foot equivalent units (TEUs) in 2021. Both India and Vietnam's shipping industries are expected to continue their growth trajectory in the coming years, with the increasing demand for goods and the expansion of trade creating opportunities for the sector. As such, the key players in both countries' shipping industries are likely to play a vital role in the industry's continued growth and development.

3.3. Challenges faced by the shipping industry in India and Vietnam.

The Maritime sector in India and Vietnam is significant, but it also faces a number of difficulties. One of the primary challenges is the competition from other shipping nations such as China, Japan, and South Korea. These countries have larger fleets and lower operating costs, making them more competitive in the global market. Additionally, the COVID-19 pandemic has disrupted global supply chains, leading to reduced demand for shipping services and lower freight rates. Moreover, seafarers working in the shipping industry face several challenges, including long periods away from home, harsh living conditions, and limited access to medical and mental health resources. These challenges can impact the mental health and well-being of seafarers, as discussed in the previous section.

To address these challenges, stakeholders in the shipping industry need to invest in infrastructure and technology to improve efficiency and reduce operating costs. Additionally, investing in seafarer mental health can lead to better retention rates and improved job performance, ultimately benefiting the industry's long-term sustainability.

4. Impact of Mental Health on Seafarers.

The Individual and work environment factors were the two categories used to categories the factors affecting the mental health and psychological problems of sailors. At the individual and organizational levels, beneficial strategies might be developed. Promoting healthy habits like eating a balanced diet and exercising while at sea is emphasized at the individual level. The shipping company manager should preferably provide advice on how to prepare healthy daily meals utilizing a cooking class and how to improve the facilities for physical fitness. This made it simple for mariners to adopt healthy habits. Because engine noise is a subjective strain, a company manager at the organizational level equips seafarers with enough tools, such as high-quality noise protective equipment. Due to their limited work hours, seamen are always under pressure from clients or contractors when at sea. It is preferable to facilitate concrete assistance for improved communication between them. Long shifts with hazy work-rest cycles are typical among seafarers. Even though finding a secure break-rest spot can be challenging, scheduling an appropriate break time is preferable. One of the main causes of stress reaction is an unbalanced effort-reward relationship. This reward also includes career and psychological benefits in addition to financial ones. The final step is to create a suitable promotion mechanism. [10]Vairavan (2022) portrays that the plight of seafarers has become a question in the Safety Crisis, as any crew change or visit to any shore, including a pilot boarding, may introduce the virus on board despite best practices for quarantine and testing of other members on the ship.

4.1. Prevalence of mental health issues among seafarers.

Seafarers face unique challenges and stressors while at sea, leading to the prevalence of mental health issues among them. Two studies provide insight into the extent of the problem. [11]Liu et al. (2019, p. 109) surveyed seafarers and found that 25.1% reported symptoms of anxiety and depression, while 16.9% reported symptoms of psychological distress. Meanwhile, [12]Lehtinen et al. (2016, p. 249) revealed that 21.3% of seafarers experienced symptoms of post-traumatic stress disorder (PTSD. These statistics clearly illustrate the high prevalence of mental health issues among seafarers.

4.2. Consequences of poor mental health among seafarers.

Poor mental health among seafarers can have significant consequences, both for the individuals affected and the shipping industry as a whole. [11]Mental health issues can lead to decreased job performance, reduced productivity, and increased risk of accidents and injuries (Liu et al., 2019, p. 109). Additionally, poor mental health can lead to high rates of turnover and reduced retention rates, which can be costly for companies in terms of recruitment and training. Moreover, the consequences of poor mental health can extend beyond the individual seafarer, affecting their families and communities. [13]Shanmugam et al., 2019, finds that seafarers with poor mental health were more likely to experience family conflict and social isolation. The effects of mental health issues can also negatively affect relationships with colleagues, which can affect the overall team dynamic and create a less productive work environment. Additionally, untreated mental health issues can lead to more severe mental health conditions, such as PTSD, which can be debilitating and require significant medical attention (p-435).

4.3. Need for investing in seafarer mental health.

[12]Investing in seafarer mental health is crucial to promoting the well-being of seafarers and the sustainability of the shipping industry. Addressing mental health issues can lead to improved job satisfaction, reduced turnover rates, and increased productivity (Lehtinen et al., 2016, p. 250). Furthermore, investing in mental health resources can help to reduce the stigma surrounding mental health issues and promote a culture of openness and support. Several initiatives have been undertaken to promote seafarer mental health, including the [14]International Maritime Organization's Guidelines on the Provision of Mental Health Care Services for Seafarers (2016) and the Sailors' Society Wellness at Sea program. However, more needs to be done to address the unique challenges faced by seafarers and promote mental health and well-being in the shipping industry (Liu et al., 2019, p. 110).

5. Investment in Seafarer Mental Health: A Financial Analysis.

Investing in seafarer mental health is not only a moral and ethical responsibility but also a sound financial decision. The mental health of seafarers has been a long-standing issue, and its impact on the industry's financial performance cannot be ignored. In this section, we will examine the costs, benefits, and return on investment (ROI) of investing in seafarer mental health.

5.1. Costs of Investing in Seafarer Mental Health.

The costs of investing in seafarer mental health programs can vary depending on the type and extent of the program. A comprehensive mental health program that includes regular mental health assessments, counseling services, and training for crew members and management staff may have higher costs than a basic program that provides only mental health education and awareness training. [15]According to a study by the International Chamber of Shipping (ICS) and the International Transport Workers' Federation (ITF), the estimated cost of providing a comprehensive mental health program for a crew of 20 on a 12-month contract is approximately $4,000 to $6,000. This includes the cost of mental health assessments, counseling services, and training for both crew members and management staff (ICS & ITF, 2018).

While the initial costs of investing in seafarer mental health programs may seem high, they can lead to significant cost savings in the long run. Neglecting seafarer mental health can result in high turnover rates, absenteeism, and accidents, which can lead to substantial financial losses for shipping companies.

5.2. Benefits of Investing in Seafarer Mental Health.

Investing in seafarer mental health can have several benefits for shipping companies. These benefits can include:

- *Increased Productivity:* A mentally healthy crew is more productive, focused, and motivated to work. This can lead to improved performance, higher quality of work, and increased profitability for shipping companies.
- *Reduced Turnover Rates:* Investing in seafarer mental health can reduce turnover rates by providing a supportive and healthy work environment. This can lead to cost savings in recruitment and training expenses.
- *Improved Safety:* A mentally healthy crew is more alert, less prone to accidents, and better able to respond to emergencies. This can lead to cost savings in insurance premiums and legal expenses.
- *Enhanced Reputation:* Investing in seafarer mental health can enhance a company's reputation as a responsible and caring employer. This can lead to increased customer loyalty and brand recognition.

These benefits have been documented in various studies, such as the [16]European Transport Workers' Federation (ETF) and the European Community Shipowners' Associations (ECSA) study mentioned earlier (ETF & ECSA, 2018). In summary, investing in seafarer mental health can have significant positive impacts on shipping companies, including increased productivity, reduced turnover rates, improved safety, and enhanced reputation. These benefits are supported by several studies and can result in substantial cost savings and increased profitability for companies.

5.3. Return on Investment for Seafarer Mental Health Programs.

The ROI for seafarer mental health programs can be difficult to quantify, as the benefits of investing in mental health may not be immediately apparent or measurable. However, several studies have attempted to estimate the ROI of investing in seafarer mental health programs.

[16]According to a study by the European Transport Workers' Federation (ETF) and the European Community Shipowners' Associations (ECSA), investing in seafarer mental health can result in a return of $2.50 for every dollar invested (ETF & ECSA, 2018). This ROI is based on the assumption that investing in mental health can lead to reduced turnover rates, improved safety, and increased productivity. Another study by the [17]World Maritime University (WMU) estimated that investing in seafarer mental health can lead to a 2.7% reduction in the cost of accidents and incidents (WMU, 2018). This reduction in costs can be attributed to improved safety and reduced insurance premiums.

In conclusion, investing in seafarer mental health is not only a moral and ethical responsibility but also a sound financial decision. While the initial costs of investing in mental health programs may seem high, they can lead to significant cost savings in the long run.

6. Case Study: Seafarer Mental Health Programs in India and Vietnam.

Managing mental health is still a highly challenging issue to address and solve because of the strain on seafarers' physical and mental health caused by their demanding jobs, harsh conditions, constant pressure, and greater responsibilities. [18]AP Companies are providing "mental health support for seafarers working onboard ships, and during their time off, for some years now. Sometimes as a result of such therapy we have been able to help the Ship Maser resolve complicated situations conditions and consequences". The AP Company also provided the acute depression and needed emergency psychiatric treatment.

6.1. Overview of Mental Health Programs for Seafarers in India and Vietnam.

India and Vietnam are major suppliers of seafarers to the global maritime industry. Both countries have recognized the importance of seafarer mental health and have implemented various programs to address this issue. In India, the [19]Directorate General of Shipping has launched a Mental Wellness Program

for Seafarers (MWPS) in collaboration with the National Institute of Mental Health and Neurosciences (NIMHANS). The program provides free counseling and mental health services to seafarers and their families. It also includes mental health awareness training for seafarers and training for doctors and nurses to provide mental health support on board ships (DG Shipping, 2021). In Vietnam, the Vietnam Maritime Administration has implemented a Mental Health Care Program for Seafarers (MHCP). The program provides mental health support to seafarers and their families through a network of mental health clinics located in major seaports across the country. The clinics provide counseling services, mental health education, and training for healthcare providers and ship operators (Vietnam Maritime Administration, 2021)[7].

6.2. Successes and Challenges of These Programs.

The mental health programs in India and Vietnam have had some successes, but also face challenges. The MWPS program in India has been successful in providing mental health services to seafarers and their families. According to a study by the Indian Journal of Psychiatry, the program has provided counseling services to over 3,000 seafarers and their family members since its inception in 2017 (Singh et al., 2020)[20]. The program has also raised awareness about mental health issues among seafarers and has helped to reduce the stigma associated with mental illness.

However, the MWPS program faces challenges in terms of accessibility and outreach. Seafarers who are at sea may not have access to mental health services, and those who are in remote areas may face difficulty in accessing the services. There is also a lack of awareness among some seafarers about the availability of mental health services (Singh et al., 2020)[20].

The MHCP program in Vietnam has also had some successes. [21, 22] According to a study by the Journal of Transport Economics and Policy, the program has provided mental health services to over 10,000 seafarers since its inception in 2018 (Nguyen et al., 2021). The program has also helped to raise awareness about mental health issues among seafarers and has improved the mental health literacy of healthcare providers and ship operators.

However, the MHCP program faces challenges in terms of sustainability and funding. The program is currently funded by the Vietnam Maritime Administration, but there are concerns about the long-term financial sustainability of the program. There is also a need to improve the quality and availability of mental health services in some areas (Nguyen et al., 2021)[23].

6.3. Cost-Benefit Analysis of the Mental Health Programs.

The cost-benefit analysis of the mental health programs in India and Vietnam is difficult to quantify, as the benefits of investing in mental health may not be immediately apparent or measurable. However, these programs can lead to significant cost savings in the long run by reducing turnover rates, improving safety, and increasing productivity. According to a study by the [24]International Transport Workers' Federation (ITF), seafarers who experience mental health issues are more likely to leave their jobs, resulting in recruitment and training costs for shipping companies (ITF, 2018). The study also found that mental health issues can lead to increased accidents and incidents, resulting in higher insurance premiums and legal expenses (ITF, 2018).

[25]Abila et al., (2023) describes that the "seafarers may not see a priorities the physical and mental health support directly impacting their well-being. Nevertheless, there are some fundamental changes in the maritime industry in using technology to improve the MH of seafarers and their overall well-being, such as the development of MH applications ("apps"), helplines, or websites, coupled with the growing comfort of seafarers to use ICT". Investing in seafarer mental health programs can help to reduce turnover rates, improve safety, and increase productivity. This can lead to cost savings in the long run for both the shipping companies and the overall economy. For instance, a report by the [26]World Health Organization (WHO) estimated that for every dollar invested in treating depression and anxiety, there is a return of four dollars in improved health and productivity (WHO, 2016). This shows that investing in mental health programs can yield significant returns on investment, both in terms of monetary benefits and improvements in human well-being.

[27]Barker, R (2018) defines that "the maritime industry has started to increase its focus on the mental health of seafarers because at the end of the day it is in their best interests. Mental health issues on board have both a financial cost and a human cost. If a seafarer has a mental health crisis on board and they have to be replaced then financial costs will be incurred in terms of replacement crew, medical expenses and possibly time delays as well". Furthermore, mental health programs can also have a positive impact on the overall economy by reducing the burden on healthcare systems and increasing workforce participation rates. Investing in mental health programs can help to reduce these costs by providing early intervention and prevention services that can help individuals stay healthy and productive.

In addition, mental health programs can also have a positive impact on social outcomes, such as reducing stigma and discrimination against individuals with mental health problems. This can lead to a more inclusive and supportive society, which in turn can improve mental health outcomes and overall well-being. Overall, while the immediate benefits of investing in mental health programs may not be easily quantifiable, the long-term benefits are significant and can lead to cost savings, improved productivity, and a more inclusive and supportive society. It is crucial that governments and organizations prioritize mental health and invest in evidence-based programs that can help individuals, families, and communities thrive.

Conclusions

Investing in seafarer mental health is crucial for the well-being of seafarers and the safety of the shipping industry. Mental health issues can lead to decreased job satisfaction, increased turnover rates, and impaired decision-making abilities, compromising the safety of ships and their crews. In contrast, investing in seafarer mental health can lead to improved job satisfaction, increased productivity, and enhanced safety. In this paper,

we explored the challenges faced by seafarers regarding mental health, the costs and benefits of investing in seafarer mental health, and the successes and challenges of mental health programs in India and Vietnam. We emphasized the need for continued investment in seafarer mental health and highlighted the positive impact such investment can have on seafarers' well-being and the safety of the shipping industry. Despite progress made in addressing seafarer mental health issues, much work remains to be done. Future research should focus on developing more effective prevention and intervention programs tailored to the unique needs of seafarers. Continued investment in seafarer mental health programs is necessary to ensure their sustainability and reach a greater number of seafarers. In conclusion, investing in seafarer mental health is not only the right thing to do but also a smart business decision. By prioritizing the well-being of seafarers, we can improve safety, increase productivity, and contribute to a more prosperous shipping industry.

References.

1. World Health Organization, Mental disorders, https://www.who.int/news-room/fact-sheets/detail/mental-disorders accessed on 28.06.2023.
2. Bohlken, J., Schömig, F., Lemke, M. R., & Pumberger, M. (2019). Anxiety, depression, and posttraumatic stress disorder in seafarers: A systematic review and meta-analysis. Journal of Affective Disorders, 245, 98-107.
3. International Transport Workers' Federation (2021). Mental health of seafarers. Retrieved from https://www.itfglobal.org/en/transport-sectors/maritime/mental-health-seafarers.
4. International Maritime Organization (2019). Seafarer welfare and safety: Improving mental health. Retrieved from https://www.imo.org/en/OurWork/Conferences/Documents/SEEMP%204/SEEMP%204%20Paper%20presented%20by%20IMO.pdf.
5. Seafarers Trust, https://www.seafarerstrust.org/wpcontent/uploads/2019/11/ST_MentalHealthReport_Final_Digital-1-.pdf (accessed on 28.06.23).
6. International Transport Workers' Federation. (2018). Seafarers' mental health and wellbeing. https://www.itfseafarers.org/sites/default/files/2018-05/ITF_seafarers%27%20mental%20health%20and%20wellbeing%20report.pdf.
7. Vietnam Maritime Administration. (2021). Mental health care program for seafarers. http://www.vma.gov.vn/en-US/For-mariners/Mental-health-care-program-for-seafarers-31.htm.
8. Government of India Ministry Shipping, New Delhi, Annual Report 2016-2017, https://shipmin.gov.in/sites/default/files/2016-17%20English.pdf.
9. Maritime Transport, (2021), Trends and Geography of World seaborne trade in 2021, https://hbs.unctad.org/world-seaborne-trade/.
10. Vairavan, C (2022). An Overview of the Impact of the Pandemic on Seafarers': Mental and Physical Health, Journal of Maritime Research, Vol. XIX, No.I, pp 36-39.
11. Liu, Y., Chen, J., Li, X., Li, W., Zhu, J., He, Q., ... Chen, J. (2019). Mental health status and related influencing factors among Chinese seafarers. International Maritime Health, 70(2), 107-112. https://doi.org/10.5603/IMH.2019.0019.
12. Lehtinen, S., Väänänen, A., & Ranta, R. (2016). Do psychosocial factors predict the incidence of post-traumatic stress symptoms among seafarers? A prospective cohort study. Journal of Occupational Health, 58(3), 246-256. https://doi.org/10.1539/joh.15-0274-OA.
13. Shanmugam, V. K., Clavarino, A. M., Wu, Q. Q., Luo, Y., Liu, Y. H., & Wang, W. J. (2019). Prevalence and correlates of psychological distress among seafarers: A cross-sectional study. BMC Public Health, 19, 847. https://doi.org/10.1186/s12889-019-7167-9.
14. International Maritime Organization. (2018). IMO/ILO/WHO Joint Working Group on Health of Seafarers. Retrieved from https://www.imo.org/en/MediaCentre/HotTopics/Pages/Health-of-seafarers.aspx.
15. International Chamber of Shipping, & International Transport Workers' Federation. (2018). Guidelines on the provision of mental health and wellbeing support for seafarers. https://www.ics-shipping.org/docs/default-source/resources/health-wellbeing-and-medical/mental-health-and-wellbeing/guidelines-on-the-provision-of-mental-health--and-wellbeing-support-for-seafarers.pdf?sfvrsn=8c5f5ee-5_6.
16. European Transport Workers' Federation, & European Community Shipowners' Associations. (2018). Investing in seafarers' mental health: A guide for European shipowners and seafarers' unions. https://www.itfglobal.org/sites/default/files/safe_workplaces_docs/ETF%20ECSA%20Investing%20in%20Seafarers%20Mental%20Health%20%282018%29.pdf.
17. World Maritime University. (2018). A study of seafarers' health and wellbeing: Analysis of the IMO 2016 international survey of seafarer wellbeing and health. https://commons.wmu.se/cgi/viewcontent.cgi?article=1138&context=all_dissertations.
18. AP Companies (2022). Mental health support for seafarers, https://www.itij.com/latest/long-read/mental-health-support-seafarers.
19. Directorate General of Shipping. (2021). Mental wellness program for seafarers (MWPS). https://www.dgshipping.gov.in/WriteReadData/userfiles/file/Mental-Wellness-Program-for-Seafarers-01-Jan-2021.pdf 20. Singh, A. R., Parmar, A., Ganjekar, S., Parikh, R., & Shanbhag, D. (2020). Seafarers' mental wellness program in India: Challenges and opportunities. Indian Journal of Psychiatry, 62(Suppl 3), S423–S427. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8041650/.
20. Nguyen, L. H., Vu, L. V., Vu, T. T., Vu, P. H., & Ha, G. T. (2021). The mental health care program for seafarers in Vietnam. Journal of Transport Economics and Policy, 55(1), 63–77. https://www.jtep.com/abstract.asp?id=3841.
21. Nguyen, T. (2021). Vietnam's shipping industry: Opportunities and challenges. Retrieved from https://english.the-

saigontimes.vn/79968/vietnam-s-shipping-industry-opportunities-and-challenges.html.

22. Nguyen, T. L. T., Nguyen, T. P., & Tran, V. L. (2021). Mental health care program for seafarers: The case of Vietnam.
23. International Transport Forum. (2019). Outlook for the shipping industry. Retrieved from https://www.itf-oecd.org-/outlook-shipping-industry-2019.
24. Abila, S, Kitada, M, Malecosio, S, Tang, L, Subong-Espina, R (2023) Empowering Seafarers as Agents of Their Mental Health: The Role of Information and Communication Technology in Seafarers' Well-Being, Inqury, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC100377-25/, doi: 10.1177/00469580231162752.
25. World Health Organization. (2019). Mental health of seafarers: Review of the existing research and recommendations for future action. Retrieved from https://www.-who.int/occupational_health/publications/mental-health--seafarers/en/.
26. Barker, R (2018), Mental health onboard: Assessing the Human and Economic cost, https://safety4sea.com/cm-mental-health-onboard-assessing-the-human-and-economic-cost.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 57–61

ISSN: 1697-4840, www.jmr.unican.es

Shape Optimization of Remote Operated Vehicle Structure Using Finite Element Method

Budianto[1,2,*], Imam Sutrisno[1,3], Muhammad Basuki Rahmat[1,4]

ARTICLE INFO

Article history:
Received 4 May 2023;
in revised from 28 Jun 2023;
accepted 29 Jun 2023.

Keywords:
Mass, optimization, shape, ROV, structure.

ABSTRACT

Analysis for optimizing the mass that can apply to the Remote Operated Vehicle (ROV) structure, it is necessary to do a shape optimization analysis on the structure. Because the presence of a heavy structure in the ROV will cause the motion to decrease and tend to require a lot of power in the ROV, it is necessary to conduct a study for structure optimization. Before optimizing to apply, the structure analysis must be safe and strong enough to do a review to analyze static, vibration, and buckling loads using finite element. Shape optimization will provide a level of structure that is strong but not over-strength. It will also provide economic value benefits regarding material requirements designed at ROV. In addition to minimizing the condition of excess strength in the ROV structure that results in the high cost of making these structures, or can realize low-cost technology by ensuring the structure remains strong. The mass of the left or right cover on the ROV structure with an initial weight of 1.8 kg while the results obtained after the optimization of the structure obtained results of 1.3 kg so that the material can reduce mass by 25%.

1. Introduction.

To optimize the gravity of the ROV construction that has been designed, the ROV must re-design the structure to have a light construction weight so that the thrust can be optimum in its operations. In addition to minimizing the condition of excess strength in the ROV structure that results in the high cost of making these structures or creating low-cost technology, by ensuring the structure remains strong. In the initial stages of designing, the ROV designs aluminum material with marine used specifications. At first the design of the existing ROV can do review in the following picture below (see figure 1).

Figure 1: General structure of existing ROV.

Source: Authors.

The components of the ROV part can be categorized into constituent parts, including the structure of the ROV, driving motor, mainboard, and control system.

[1]Politeknik Perkapalan Negeri Surabaya, Jalan Teknik Kimia, Keputih, Sukolilo Surrabaya (Indonesia).

[2]Assistent Professor of Ship Design and Contruction of the Department of Shipbuilding Engineering. E-mail Address: budianto@ppns.ac.id.

[3]Assistent Professor of Otomation Enginering of the Department of Marine Electrical Engineering. E-mail Address: imam_sutrisno@ppns.ac.id.

[4]Assistent Professor of Electrical Engineering of Department of Marine Electrical Engineering E-mail Address: mbasuki.rahmat@ppns.ac.id.

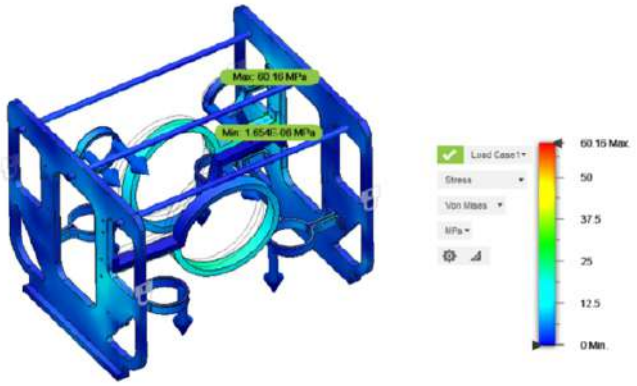
[*]Corresponding author: Budianto. E-mail Address: budianto@ppns.ac.id.

Analysis structure to ensure the strength of the structure that remains strong in accepting the load in operation required supporting calculations. The structure is divided by numerical pattern into structural elements that apply to existing placement and loading conditions. One of the supporting technologies performs calculations using the finite element method. In the previous research, several analyzes carry to ensure the strength and safety of the structure, including static load analysis, capital frequency analysis, and Buckling analysis. Where results can be shown as follows:

1.1. Static analysis.

Static analysis is a structural analysis to determine the stress and deformation by comparing with the allowable stress and allowable deformation values. The actual condition of the Voltage in the ROV structure is still Fulfilled can be shown in the picture below (figure 2). The static analysis quality depends on the analysis techniques used by program software, but the best combination of such techniques may be different for different program sofftware (Jihyeok Park, 2022).

Figure 2: Static load analysis of ROV.



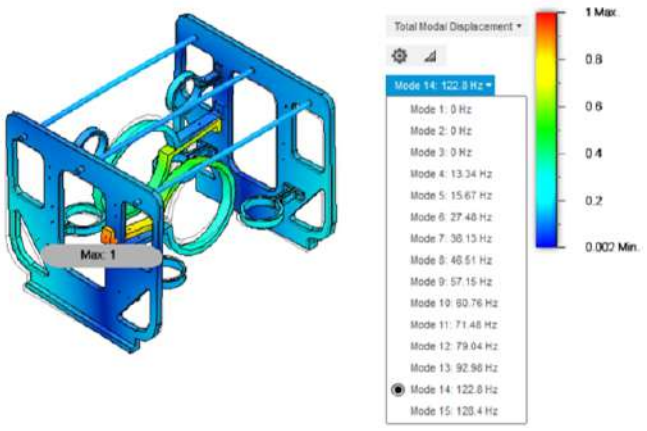
Source: Authors.

The structure can be quite strong and safe in operation if the value of the stress that occurs is smaller than the allowable stress value (Budianto, 2018). The allowable stress has included elements in the material and safety factors.

1.2. Modal frequency analysis.

In the condition of vibrations that occur due to the excitation frequency of the ROV's driving force (motor and propeller), it is necessary to analyze the capital frequency to cope with excessive vibration in the ROV structure (Mohammad Basuki Rahmat, 2020). An excessive vibration occurs if the value of the excitation frequency is the same as the natural frequency value. The modal frequency analysis calculates the natural frequency value owned by the ROV structure. In the analysis of natural frequency, called eigenvalue structure, the natural frequency can be calculated by calculating from several components of mass and stiffness. The results of the analysis of capital frequency can be shown in the analysis of capital frequency in the figure below (figure 3).

Figure 3: Modal frequency analysis of ROV.



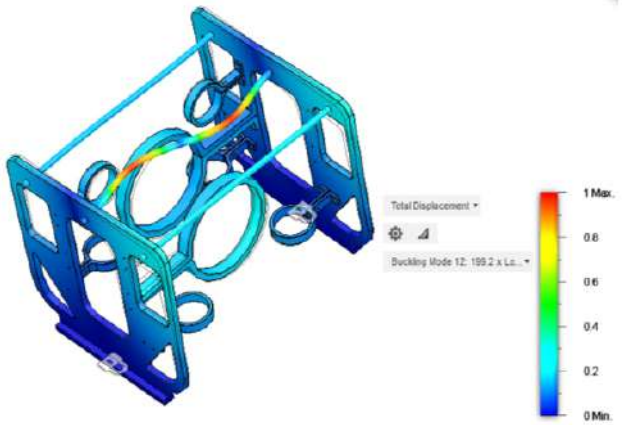
Source: Authors.

The analysis and calculation results show that the natural frequency value is not the same as the value of the excitation frequency that occurs from the driving force (motor and propeller), so it can be said that the structure is still safe in excess vibration conditions.

1.3. Buckling Analysis.

Bending load analysis is indispensable in maintaining structural strength at ROV. The bending load is hazardous to the structure, which can cause the structure to break or deform. So a buckling analysis is performed with the following results figure below (figure 4).

Figure 4: Buckling analysis of ROV.



Source: Authors.

In the picture above, the Buckling condition is still safe from the condition of the allowed buckling load on the ROV structure condition. The maximum bending risk is most at risk in the connection section of the ROV structure.

The analysis structure does optimize the mass load designed on the ROV structure, and it is necessary to do a shape optimization analysis. So this will provide a level of structure that is

strong but not strength. It will also provide economic value benefits regarding material requirements designed at ROV. Somebody can do aspects of shape optimization Aspects of shape optimization in three activities the form geometric space, concept analysis, and efficient optimization (Welker, 2022).

2. Analysis Process.

Finite element application to analyze the structure. Finite element provides various structural analysis methods to carry out on finite elements in the structure. In the development of finite elements, analytical technology uses by various engineering. The objects are discretized into constituent elements. (Suzana Ereiz, 2022) The application of finite elements can be used in some structural analyses, flow-form, and others. At this time of designing structures up to date, the density and magnitude of the load have increased, and the requirements for regulation have also become more stringent (Gang Bao, 2022).

RUV (Remote Underwater Vehicle) is a robotic device that can take data in water depths. So it can replace the role of divers in the investigation of objects that are in the sea. In RUV, the fundamental difference with the control system is that of the cable system. In technical terms, several experiments characterize optical links and demonstrate remote control in RUV. The purpose of the ROV is to perform translational, ascent, descent, and rotational movements on three axes (Aguirre-Castro, 2019).

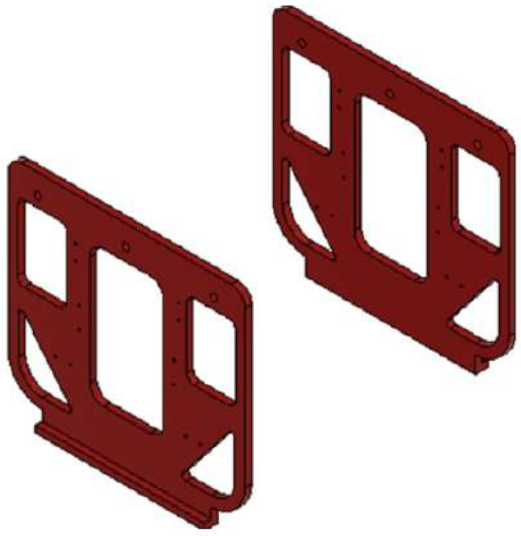
Lightweight materials in general and alumunium alloys in particular are increasingly becoming important engineering materials in order to improve the sustainability aspects of engineering products for design and analysis process (Ul Haq M, 2021). Two digits of 60xx alloys commonly used in the marine industry are 6061-T6 and 6082-T6. Such materials usually have resistance in corrosive operational conditions. This is evidenced by the shallow rate of corrosion and marine life attached to the hull or building structures.

CAD and Material Definition are required in the analysis of this study. The beginning of the analysis can be done by making CAD with existing components. Then do the material definition using 5083 marines used aluminum alloy material. The meshing process is carried out to discuss the object into the ROV constituent elements, which are conditioned in fine mesh conditions. Load in constrain is the loading process placed in the structure's loading area, which is then entered for the value of the force acting. It's as placement is applied at the bottom of the structure. The presence of stresses acting on the structure that can continuously cause work-related fatigue depends directly on the characteristics of the working environment facing the object of the structure, particularly the type of demands imposed by the task (Angel M. Costa, 2020). Analysis Process is the analysis process refers to the method of form optimization by getting the optimum mass design in the ability to accept existing loading.

2.1. Analysis Result.

In-shape optimization analysis refers to the target Left and Right Cover Weight. It indicates the weight that can be reduced by shape-optimized structure. The components that are modeled on the Left and Right Cover are shown in the following see figure below (figure 5).

Figure 5: Left and right body cover to optimized.



Source: Authors.

On the physical material, the material shows aluminum material 5083 (Fusion360, 2022), which on the left and right cover components are designed. The existing mass can show a value of 1.8 kg. The physical table is shown in the table below.

Table 1: Physical material properties.

Material physical properties		Units
Material	Alumunium 5083	
Area	1.670E+05	mm^2
Density	2.660E-06	kg/mm^3
Mass	1.774	kg
Volume	6.668E+05	Mm^3

Source: Properties form Autodesk Fusion 360 material properties.

Bounding Box is an analysis structure package facility produced. It gets information on emphasis and moment of inertia given information from CAD in the form of bounding boxes (Autodesk, 2013). Computer Aided Design (CAD) is the use of computer based software to aid in design modeling, design analysis, design review, revision, and design documentation (Bonsa Regassa Hunde, 2022). The bounding box values are obtained from the table result below (see table 2).

The aim is to generate optimal material distributions with high-quality interfaces within a uniform geometric representation for topology and shape optimization to apply this case (Bartz R, 2022). Analysis to reduce the weight required form optimization by applying a reduction of 25% of its weight so that the target can be reduced to 75%. Where the results of Shape Optimization are shown in the following results (seee

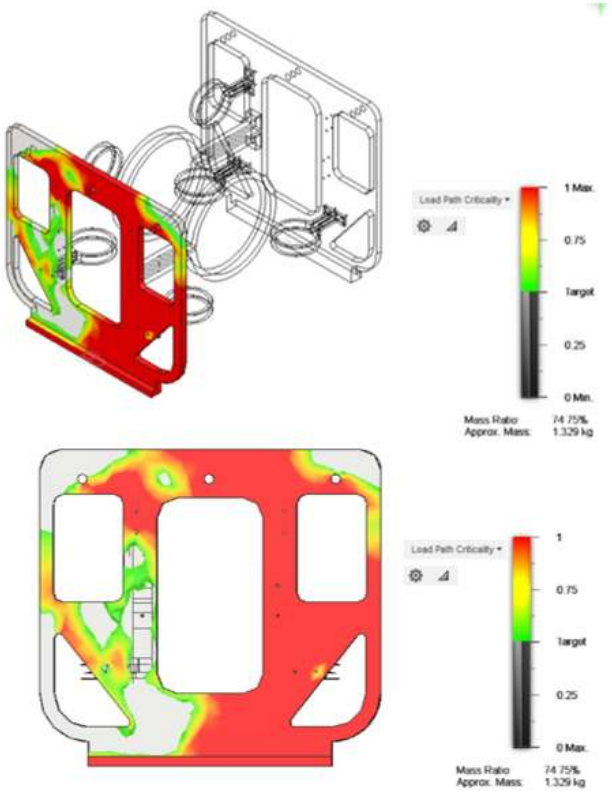
Table 2: Object optimatization properties.

Object Shape Optimization		
Length	200.00	mm
Width	325.00	mm
Height	350.00	mm
Center of mass		
X	357.072	mm
Y	298.47	mm
Z	330.141	mm
Moment of Inertia at Center of Mass		
Ixx	3.794E+04	$kgmm^2$
Ixy	-99.895	$kgmm^2$
Ixz	-0.004	$kgmm^2$
Iyx	-99.895	$kgmm^2$
Ixz	1.766E+04	$kgmm^2$
Iyz	-1.198	$kgmm^2$
Izx	-0.004	$kgmm^2$
Izx	-1.198	$kgmm^2$
Izz	2.032E+04	$kgmm^2$

Source: Authors.

figure 6).

Figure 6: Shape Optimization Result.



Source: Authors.

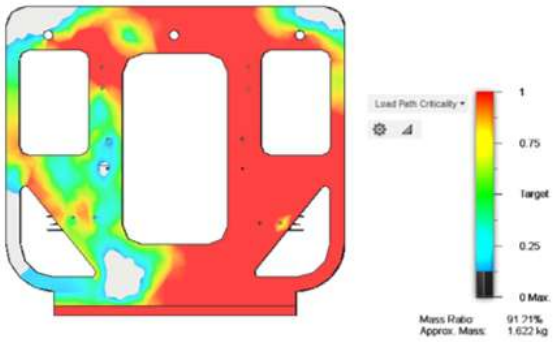
While the mass of the left or right cover on the ROV structure with an initial weight of 1.8 kg, while the results obtained after the optimization of the structure obtained results of 1.3 kg so that the material can save 25%.

3. Discuss and recomendation.

3.1. Mass application.

The recommended reduction is only applied 10% of the weight of the construction left or right cover to maintain strength and increase the value of the existing safety factor risk. The results can be shown as follows for the application of the design.

Figure 7: Mass Reduction Application.

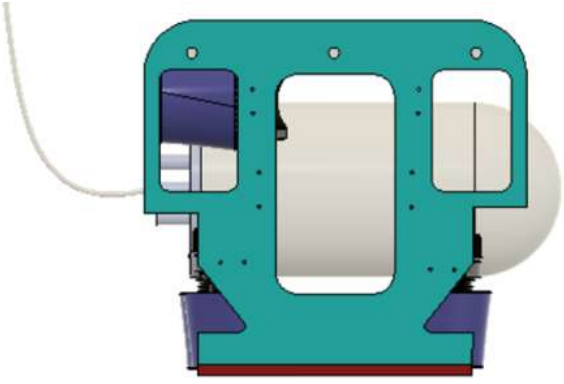


Source: Authors.

3.2. Recommendation.

The design after optimization can be shown in the form of ROV structure models can be shown in the picture below as follows:

Figure 8: Final optimization design of ROV.



Source: Authors.

Conclusions

The mass of the left or right cover on the ROV structure with an initial weight of 1.8 kg while the results obtained after the optimization of the structure obtained results of 1.3 kg so that the material can reduce mass by 25%.

Acknowledgements.

Thanks to the Ministry of Research, Technology, and Higher Education for applied research grants and the support of fellow PPNS lecturers.

References.

Aguirre-Castro, O.-G. E.-G. (2019). Design and construction of an rov for underwater exploration. Journal Sensors, 1-25.

Angel M. Costa, R. B. (2020). Fatigue due to on board work conditions in merchant vessels. Journal of Maritime Research, 37-46.

Autodesk. (2013). Autodesk Alias Automotive. Toronto: Visual Evaluation of Surface Area.

Bartz R, F. T. (2022). Density-based shape optimization of 3D structures with mean curvature constraints. Structural and Multidisciplinary Optimization.

Bonsa Regassa Hunde, A. D. (2022). Future prospects of computer-aided design (CAD) – A review from the perspective of artificial intelligence (AI), extended reality, and 3D printing. Results in Engineering , 100478.

Budianto, t. w. (2018). Strength Analysis on Ship Ladder Using Finite Element. Journal of Physics: Conference Series (p. 012043). Bristol: IOP science.

Fusion360, A. (2022). Mechanical properties of materials. California: Autodesk.Gang Bao, P. L. (2022). Finite Element Methods. Applied Mathematical Sciences (Switzerland), 684-723.

Jihyeok Park, H. L. (2022). A Survey of Parametric Static Analysis. ACM Computing Surveys.

Mohammad Basuki Rahmat, I. S. (2020). Vibration Analysis of Ship-RUV Structure In Operational. International Conference Earth Science & Energy, 012045.

Suzana Ereiz, I. D.-A. (2022). Review of finite element model updating methods for structural applications. Structures.

Ul Haq M, R. A. (2021). Potential of AA7075 as a tribological material for industrial applications - A review. Indian Journal of Pure and Applied Physics.

Welker, K. (2022). Suitable Spaces for Shape Optimization. Applied Mathematics and Optimization, 100849..

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 62–67

ISSN: 1697-4840, www.jmr.unican.es

Combining Wind Power, Aquaculture and Marine Tourism: A novel multi-use blue economy concept for Bangladesh

Shahriar Ahmed[1,*], A.S.M Mahadi Hassan[1], Md. Mashiur Rahaman[1], N. M. Golam Zakaria[1]

ARTICLE INFO

Article history:
Received 8 May 2023;
in revised from 28 Jun 2023;
accepted 30 Aug 2023.

Keywords:
Multi-use, Blue economy, Wind energy, Aquaculture, Marine Tourism, NPV.

ABSTRACT

Multi-use, Blue economy, Wind energy, Aquaculture, Marine Tourism, NPV Bangladesh is blessed with 166,000 sq. km of ocean territory which can be best utilized for sustainable development by innovative implementation of blue economy concept. The country is yet to assess various blue growth concepts within the local EEZ. One such worldwide increasingly popular concept is multi-use blue economy. Literature study shows that any study on viability of multi-use in the local EEZ is almost nonexistent . This paper endeavors to provide a first insight into the concept through a proposed multi-use project for the country. The synergy of three different potential sectors : wind energy, aquaculture and marine tourism have been considered for the project. A concept design is developed keeping in mind physical condition and ecological richness suitable for such multi-use combination. Basic economic analysis is also provided for the proposed project with a sensitivity analysis. The result imply that this project can be an economically viable initiation for multi-use blue economy for Bangladesh and can be a model for promoting the development of new blue economy sectors which often require substantial amount of subsidy especially offshore wind farms. Further aspect of the project where research is required is also highlighted.

1. Introduction.

Multi-use activities can imply different activities constructed upon a single installation, frequently referred to as Multi-Purpose Offshore-Platforms, or they can simply refer to the sharing of the same marine space. The offshore platforms used by the oil and gas industries dating back to the 19th century served as inspiration for the construction of modern floating multi-use platforms and subsea engineering. Many maritime nations are finding themselves in a position to take immediate action to address the problem of the growing competition for space in coastal regions. As a result, there is currently a global drive to identify synergies between marine exploitation businesses and sectors of the Blue Economy in multi-use configurations. Combining many operations into one platform or area helps to reduce infrastructure costs and makes the most of available marine space (Ramos, Díaz and Guedes Soares, 2022).

Following the resolution of the maritime boundary delimitation conflict with Myanmar and India in or around 2014, discussions on the blue economy began in Bangladesh.

Without a doubt, Bangladesh's future development and economic growth will be international trade, the use of marine mineral resources for long-term energy security, the proper management of marine fisheries, and the preservation of the marine environment and biodiversity (Hussain et al., 2018). But so far diversification and growth of new blue economy sectors is rather limited. In this paper we have developed a proposed concept design in the EEZ of Bangladesh and through a preliminary economic analysis endeavored to unravel its relevance and significance there. The key objective of this paper has been to suggest and justify multi-use concept as a solution to the struggle for the new sectors development. Multi-use concept is pioneered and heavily researched in European littoral countries

[1]Department of Naval Architecture & Marine Engineering, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh.
[*]Corresponding author: Shahriar Ahmed E-mail Address: fahimst2022@gmail.com.

many of which have diverse blue economy sectors (Ramos et al., 2022). EEZ of various countries around North Sea are already getting saturated by various marine uses and Marine Spatial Planning (MSP) is getting challenging for the stakeholders (BSH - Maritime Spatial Planning, n.d.).

So, multi-use concept is being adopted there for optimum use of maritime space. Coming back to the case of Bangladesh where most of the blue economy sectors are underdeveloped multi-use concept can be seen as a long-term strategy to reduce competition for space among would be sectors. This paper is only focused to economic feasibility of multi-use project and there by aimed at suggesting it at as a method of new sector development. To achieve that three particular sectors are chosen for synergy : offshore wind farm, marine offshore aquaculture and marine tourism. All three sectors have potential to large scale expansion in the EEZ of Bangladesh .Furthermore, these sectors offer various inherent opportunity for integration and their compatibility is well established by existing multi-use projects (Schultz-Zehden et al., 2018).

2. Concept design.

2.1. Overview.

In this section, we'll discuss about the design that we have conceptualized for this project. The project would be situated six kilometers off Cox's Bazar's shore. In total, 12 bottom-fixed wind turbines would be present, forming a rectangular outline. In between the turbines, four square-shaped mussel culture plots would be installed. From the Cox's Bazar tourist attractions, the location would be conveniently accessible. A multipurpose vessel would be set aside for the project to be used for maintenance of the wind turbines, mussel culture, and sightseeing excursions around the project. For better comprehension, the proposed project's spatial arrangement is fitted into a Google Earth map in Figure 1. The six white dots represent the location of wind turbines and the white squares in between them represent the mussel plots. The corresponding 3D model of the project is presented in Figure 3.

2.2. Location Selection.

Cox's Bazar coastal area seems to be the most suitable for this particular multi-use project for several reasons. Unsurprisingly, synergy of other marine sectors with tourism is feasible close to existing tourism spots(Schultz-Zehden et al., 2018). All of Bangladesh's south-east offshore regions have wind conditions that are favorable for wind farms, with wind speeds averaging 6-7.29 m/s.(Nadi et al., 2019). At the same time, Cox's Bazar coastal region is suitable for mussel culture (perna viridae)(Shahabuddin et al., 2010).The first large scale onshore wind farm is also under construction on the outskirts of Cox's Bazar (Khurushkul Wind Farm - Global Energy Monitor, n.d.). So, stakeholders can benefit from the experience of the current project when considering further wind farm projects in the vicinity of the existing one. All these factors combined make Cox's Bazar the perfect spot for the multi-use project we are conceptualizing in this paper.

Figure 1: Spatial planning of the project off the coast of Cox's Bazar.

Source: Google Earth, 2022.

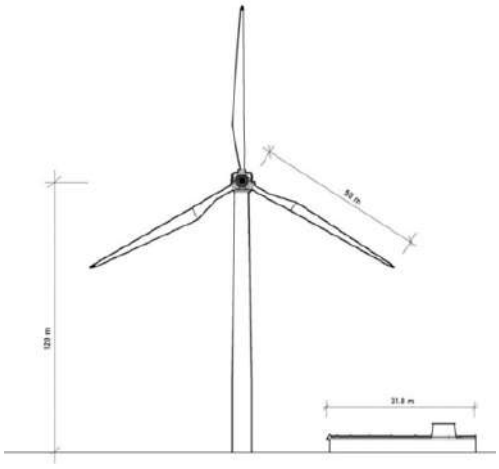
2.3. Wind Farm Design.

Despite the fact that a wind turbine's capacity is typically 5 MW, we chose 3 MW units that are comparable to those in the Khurushkul Project. Because they affect both investment spending and operation and maintenance costs, the distance to shore and sea depth are significant from an economic perspective. As the distance from the shoreline increases, so do the expenses of installation and grid connection. Moreover, the price of foundations rises as water depth does. Though 18.8 kilometers is the typical distance from the coast first farms are frequently found close to the water. The first wind farm in the States, located in Rhode Island, is barely 4.5 km from the coast, while Shanghai DBOWF, China's first offshore wind farm, is just 8–13 km away. Small distances have many benefits, including significantly lower capital and maintenance costs (Díaz and Guedes Soares, 2020). Short distance also facilitate tourism activities like in Rhode island ,USA (Trandafir et al., 2020). Thus, considering all this factors a short distance of 6 km is assumed in this paper. The water depth at the project site is assumed to be 10 m which is the average depth of water within the territorial sea of Bangladesh (Mustafa, 2003). The wind turbine rotor diameter and hub heights are calculated with respect to the selected rated power (Díaz and Guedes Soares, 2020).

2.4. Mussel Culture Design.

Here for simplicity and being similar in context , we adopted the offshore longline mussel culture farm model used in (Buck, Ebeling and Michler-Cieluch, 2010) which was designed for the German North Sea area. V shaped parallel longlines with the capacity for both producing consumption mussel and seed mussel were used . However, we focused only on the consumption

Figure 2: Model wind turbine along with the vessel.



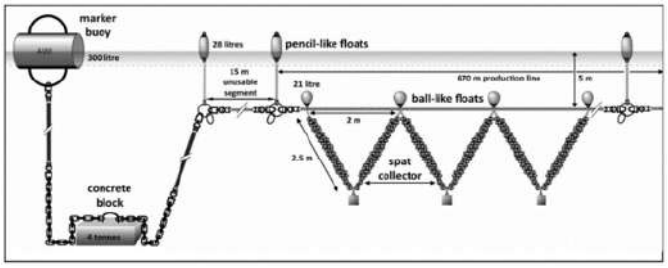
Source: Authors.

Figure 3: Aerial view of the 3D model.

Source: Authors.

size mussel in the concept design . Furthermore, Green mussel is considered here rather than Blue Mussel which is endemic to North Sea region. The key dimensions of the mussel culture longline are kept unchanged and can be seen in Figure 4.

Figure 4: Submerged longline system design with a V-shaped spat.



Source: Buck et al., 2010.

2.5. Tourism Integration.

Synergies of marine tourism with other sectors of this project can be done in several ways specially with the offshore wind farm. Most of the activities is conducting sightseeing trips around the OWFs which is the only one considered in this paper. The boat used for wind farm and mussel culture can be used for the trips and assumed to be equipped with amenities to that end. Figure 5 can give an idea about how the project would appear to the potential tourists from a close distance. All the key dimensions of the concept design are listed in Table 1.

Figure 5: View from the vessel.

Source: Authors.

Table 1: Key dimensions.

Wind turbine		Mussel culture	
Distance from shore	6000 m	Mussel longline length	700 m
Depth	10 m	Spacings between longlines	10 m
Capacity	3 MW	Mussel plot area	49 ha
Turbine number	12	Mussel plot number	4
Turbine hub height	120 m	Total area	196 ha
Rotor diameter	100 m		
Spacing between turbines	1000 m		

Source: Authors.

3. Economic analysis.

3.1. Methodology.

For the purpose of reducing complexity in an economic analysis that is still of a hypothetical nature, we collected data from relevant existing European projects. The cost benefit values of such offshore projects are influenced by myriads of internal and external factors. So, a properly rigorous breakdown of call cost benefit components is required which is beyond the scope of this paper. For simplicity we figured out the bulk cost benefit values related to this projects. The corresponding average values of these components are selected from similar European projects and transferred to the value of 2023. A 2% Inflation rate is used (European Union Inflation Rate - March 2023 Data - 2000-2022 Historical, no date). The currency used in

the analysis is US Dollar and an exchange rate of 1€ =1.05$ is used for conversion(Euro to US Dollar Spot Exchange Rates for 2022, no date). Discount rate 12% is used here which is typical for infrastructure projects in Bangladesh (Connectivity et al., 2019). To demonstrate the effect of multi-use NPV value is calculated in three different cases: 1) when only wind farm is operational 2)mussel culture is in multi-use alongside the wind farm 3) when both mussel culture and marine tourism is in multi-use with wind farm. Finally , a sensitivity analysis is outlined with respect to the inherent uncertain parameters of this proposed project.

3.2. Sector specific data sources and assumption.

3.2.1. Wind power.

There is no primary data source available for the capacity factor at our chosen site for this project. However ,one particular study shows that in onshore conditions at Cox's Bazar at the height of 120m capacity factor is 34% (Islam, Rahman and Mannan, 2016).As offshore wind farms tend to have higher capacity factors and due to uncertainty associated with the data, we have taken a conservative value of 35%. The tariff offered by Bangladesh government is 0.12 us$/kwh which at least, we assumed ,would be applicable for any future offshore wind farms (Bangoura, 2008). Life expectancy of the project is taken to be 20 years. Thus, yearly energy production from the 8 wind turbines comes out to be 11036 MWh and yearly revenue is 4.64 m€. Now, the three gross components for wind farm costs are : Initial investment cost, operation and maintenance cost and decommissioning cost. A study of 2016 shows that for wind farm with shore distance 0-10 km and water depth 0-10 m average specific investment cost is 24 m€/MW and 22 m€/MW respectively(Morthorst and Kitzing, 2016). As our concept design satisfy this distance to shore and water depth criteria we chose the value 23 m€/MW. So, the initial investment cost is 82.8 m€ in the context of 2016 which when adjusted by accumulated inflation and exchange rate became 100m$ in 2023. At less than 10 km from shore average wind farm operation and maintenance cost is 24€/MWh.(Work, Jones and Adams, 2020)Similar adjustments leads to a yearly cost of 3.26 m€. And for the decommissioning cost we used a linear regression formula (Gonzalez-Rodriguez, 2017). We got a value of 688 k$ considering the capacity of the project. All the basic data regarding the wind farm segment of the project is illustrated in the Table 2.

Table 2: Wind turbine cost benefit breakdown.

Wind turbine		
Cost	Initial investment cost(m$)	100
	Operation and maintenance cost(m$)	3.26
	Decommissioning cost(m$)	6.89
Total cost (m$)		110.15
Revenue	Energy generated (MWh)	110376
	Feed in tariff(US$/kWh)	0.12
	Price(US$/kWh)	0.059
Total revenue (m$)		4.64

Source: Authors.

Table 3: Mussel culture cost benefit breakdown.

Mussel Culture		
Cost(m$)	Initial investment cost	4.93
	Longlines	0.688
	Collectors	1.647
	Buoyancy	0.11
	Stone/anchors	0.01
	Motor	0.576
	Repair/Maintenance	1.88
Revenue	Biomass per meter of collector(kg)	10
	Biomass per single longline(tons)	16.75
	Biomass per single mussel plot(tons)	11.89
	Market price per kg of mussel(US$)	2.75
Total revenue(m$)		13.1

Source: Authors.

3.2.2. Mussel Culture.

As the mussel culture model is adopted from.(Buck, Ebeling and Michler-Cieluch, 2010) For that we had to assume that mussel culture plot installation and maintenance costs in German North Sea will be almost equal to that of Cox's Bazar. So, same data is used for costs and revenue after inflation and exchange rate adjustments. However Green mussel price of 2.75 $/kg had to be used instead of blue mussel .Green mussel price in the local market of Cox's Bazar is around 3 $/kg (Shakil et al., 2019). Due to the inherent uncertainty of the data we assumed a conservative value. Cost benefit breakdown of mussel culture is given in Table 3.

3.2.3. Marine Tourism.

For being a completely hypothetical project it's nearly impossible to precisely predict the number tourist each day will turn out for sightseeing trip. To get a rough value we looked for similar beach area with multi-use of tourism along offshore wind farm already in place. Thorntonbank in Belgium is such a place that has a good match to our concept design. It is still operational and attracts approximately 10,000 people per year for boat tours to local offshore wind farms(Lal et al., 2021). In 2022 ,Belgian sea beaches in the vicinity of Thorntonbank were visited by 1.7 million tourist(Mauricio Ruiz, 2023). Whereas

Cox's Bazar hosted 3 million tourists in the same year(Need for holistic growth of Cox's Bazar, no date). If we assume a linear relation to total turnover of tourists to the number of tourists making trips to the offshore wind farms between both places, 17500 tourist turn over can be expected in the proposed project per year. Now, assuming two trips per day tourist turn out per trip is taken 25 and number of trip per year would be roughly 730. A typical mussel harvesting vessel has around 30m length . Average power and speed are respectively 450 hp and 12 kn. Now for diesel engine typical value of SFC =.40 lb. Per hp and FSW= 7.2 lb. per hp (Calculating Boat Fuel Consumption | Boating Mag, no date). Using the formula fuel consumption (GPH) =(SFC×hp)/FSW extra fuel consumption came out 25 GPH. Considering distance from shore and vessel speed it can be assumed that the vessel engine would be running 1 hr. per trip. So, per trip fuel consumption is approximately 100 L. Assuming diesel price 1 $/Liter extra fuel cost due to tourism per year comes out to be 73 k$. Usually, 5 crew is needed in a trawler of 30 m which we assumed the number of extra crew needed for conducting sightseeing trips. Salary per month offered to fishing trawler crews in Bangladesh ranges from 10,520 tk to 26,000 tk(Tk 10,520 set as minimum wage for fishing trawler workers , no date). So, the average crew wage per year is calculated to be 10 k$. The cost benefit breakdown of the tourism section is listed in Table 4.

Table 4: Tourism cost benefit breakdown.

	Tourism	
Cost	Per trip fuel cost($)	100
	Fuel cost(k$)	70
	Wages(k$)	10
Total cost(k$)		80
Revenue	Per ticket price($)	10
	Yearly trip	730
	Per trip tourist	25
Total revenue(k$)		176

Source: Authors.

4. Result.

As stated in section 3.1 we divided the analysis into three cases. The NPV values are calculated in three additional scenarios under these cases depending on the tariff rate used . The results are outlined in the Table 5 . At the base tariff of 0.12 $/KWh , case 1 is infeasible and case 2 and 3 are feasible with substantial amount of NPV values. The current electricity price in the households of Bangladesh is 0.59 $/KWh. Even at this rate case 2 and 3 remains economically feasible. And only above tariff rate of 0.139 $/KWh case 1 is feasible. So, under the assumptions we made and according to our analysis the proposed multi-use project is quite feasible economically. The positive impact of multi-use is also evident as NPV in case 2 and 3 substantially increased compared to case 1. Result of the sensitivity analysis can be found in Table 6. It is evident that NPV is much less sensitive to trip number compared interest rate, mussel price and capacity factor.

Table 5: Sensitivity Analysis results.

Tariff	0.059 $/KWh	0.12 $/KWh	0.139 $/KWh
Case 1 (NPV)	-65.7 m$	-15.42 m$	0.2 m$
Case 2 (NPV)	8.8 m$	59.1 m$	74.8 m$
Case 3 (NPV)	11.7 m$	62 m$	77.7 m$

Source: Authors.

5. Further research.

This paper is intended to work as a harbinger for multi-use blue economy concept in Bangladesh. Further more rigorous research would be vital for implementing such ambitious projects. A more accurate result could be possible by considering all cost benefit components in the context of Bangladesh which is inexhaustible. Proper sourcing of bathymetry and hydrographic data can enable these efforts. Furthermore, incorporating intangible aspects like environmental and social cost benefit can give a more holistic result. This paper is only focused on the economic analysis of the proposed project. A rigorous technical feasibility along with a comprehensive risk assessment can unravel any hidden limitations of this type of projects.

The NPV can be increased further by considering many other tourism activities triggered by the Artificial Reef effect of offshore wind farms (Pendleton, 2004).

Conclusions

Bangladesh's ocean area is almost the same size as its land area. It goes without saying that it has a lot to gain from the Blue Economy as a maritime nation. The country has taken the lead in advancing the blue economy among the Bay of Bengal's littoral nations. But to take advantage of every potential our EEZ has to offer, Bangladesh should strive for blue economy sector diversification. Furthermore, there is a looming problem of constricted marine special planning which is bound to affect every country as blue economy sees further growth. The multi-use concept can give the much needed impetus to the country's

path to a vibrant blue economy. In this paper we presented a novel proposed multi-use project for the country and subjected it to a basic economic analysis . The result imply that this type of multipurpose projects would highly feasible economically . It also signifies that our policy makers can encourage the growth of new blue economy sectors at much less subsidy by embracing the multi-use concept. So, multi-use is surely a topic to be put into further extensive research.

References.

Bangoura, O. (2008) 'The World Bank', *Annals of Tropical Medicine and Parasitology*, 102(SUPPL. 1). doi:10.1179/136485908X337463.

BSH - Maritime Spatial Planning (no date). Available at: https://www.bsh.de/EN/TOPICS/Offshore/Maritime_spatial_planning/maritime_spatial_planning_node.html) (Accessed: 17 April 2023).

Buck, B.H., Ebeling, M.W. and Michler-Cieluch, T. (2010) 'Mussel cultivation as a co-use in offshore wind farms: Potential and economic feasibility', *Aquaculture Economics and Management*, 14(4), pp. 255–281. doi:10.1080/13657305.2010.526018.

Calculating Boat Fuel Consumption | Boating Mag (no date). Available at: https://www.boatingmag.com/calculating-fuel-consumption/ (Accessed: 4 May 2023).

Connectivity, S.R. *et al.* (2019) 'SASEC Railway Connectivity: Akhaura – Laksam Double Track Project (RRP BAN 46168) 1', (November 2008), pp. 1–7.

Díaz, H. and Guedes Soares, C. (2020) 'Review of the current status, technology and future trends of offshore wind farms', *Ocean Engineering*, 209(June). doi:10.1016/j.oceaneng.2020.107381.

Euro to US Dollar Spot Exchange Rates for 2022 (no date). Available at: https://www.exchangerates.org.uk/EUR-USD-spot-exchange-rates-history-2022.html (Accessed: 17 April 2023).

European Union Inflation Rate - March 2023 Data - 2000-2022 Historical (no date). Available at: https://tradingeconomics.com/european-union/inflation-rate (Accessed: 17 April 2023).

Gonzalez-Rodriguez, A.G. (2017) 'Review of offshore wind farm cost components', *Energy for Sustainable Development*, 37(April 2017), pp. 10–19. doi:10.1016/j.esd.2016.12.001.

Hussain, M.G. *et al.* (2018) 'Major opportunities of blue economy development in Bangladesh', *Journal of the Indian Ocean Region*, 14(1), pp. 88–99. doi:10.1080/19480881.2017.1368250.

Islam, R., Rahman, N. and Mannan, A. (2016) 'Study of Wind Power in Different', pp. 1290–1299.

Khurushkul wind farm - Global Energy Monitor (no date). Available at: https://www.gem.wiki/Khurushkul_wind_farm (Accessed: 17 April 2023).

Lal, P. *et al.* (2021) 'The Potential of Offshore Wind Energy Tourism in Ocean City, New Jersey'. Available at: https://www.montclair.edu/clean-energy-sustainability-analytics/wp-content/uploads/sites/151/2022/07/offshore-wind-energy-tourism-white-paper.pdf.

Mauricio Ruiz (2023) *Belgian coast reports record inflow of foreign tourists in 2022 - Travel Tomorrow*. Available at: https://traveltomorrow.com/belgian-coast-reports-record-inflow-of-foreign-tourists-in-2022/ (Accessed: 4 May 2023).

Morthorst, P.E. and Kitzing, L. (2016) *Economics of building and operating offshore wind farms*, *Offshore Wind Farms: Technologies, Design and Operation*. Elsevier Ltd. doi:10.1016/-B978-0-08-100779-2.00002-7.

Mustafa, M.G. (2003) 'Preliminary analysis of the demersal fish assemblages in the Bangladesh waters of the Bay of Bengal', *WorldFish Center Conference 2003*, pp. 153–162.

Nadi, N.R., Bingol, F. and Badger, M. (2019) 'Offshore Wind Energy Estimation in the Bay of Bengal with Satellite Wind Measurement', *1st International Conference on Advances in Science, Engineering and Robotics Technology 2019, ICASERT 2019* [Preprint], (May). doi:10.1109/ICASERT.2019.8934915.

Need for holistic growth of Cox's Bazar (no date). Available at: https://www.thefinancialexpress.com.bd/views/views/need-for-holistic-growth-of-coxs-bazar-1644246023 (Accessed: 6 - May 2023).

Pendleton, L.H. (2004) 'Creating Underwater Value: The Economic Value of Artificial Reefs for Recreational Diving', (January 2004), pp. 1–11.

Ramos, S., Díaz, H. and Guedes Soares, C. (2022) 'Potential opportunities of multi-use blue economy concepts in Europe', *Trends in Maritime Technology and Engineering Volume 2*, (April), pp. 461–475. doi:10.1201/9781003320289-49.

Schultz-Zehden, A. *et al.* (2018) 'Ocean Multi-Use Action Plan', (727451), p. 132. Available at: https://www.submariner-network.eu/images/news/MUSES_Multi-Use_Action_Plan.pdf.

Shahabuddin, A.M. *et al.* (2010) 'Abundance, Distribution and Culture Potentials of Three Commercially Important Mollusks Species along the Coast of Bay of Bengal Pyropia spheroplast as a feed ingredients for aquatic animals View project 5-Books of colleagues View project', 6(6), pp. 754–762. Available at: https://www.researchgate.net/publication/260799062.

Shakil, A. *et al.* (2019) 'Experiences and opinions of mollusk fishers in the Cox's Bazar coast, Bangladesh', Journal of Veterinary [Preprint], (September). Available at: https://www.researchgate.net/profile/Md_Asaduzzaman2/publication/337313281_Experiences_and_opinions_of_mollusks_fishers_in_the_Cox's_Bazar_coast_of_Bangladesh/links/5dd12f914585156b3519e6cb/Experiences-and-opinions-of-mollusks-fishers-in-the-Coxs-Bazar-co.

Tk 10,520 set as minimum wage for fishing trawler workers (no date). Available at: https://www.newagebd.net/article/189531/tk-10520-set-as-minimum-wage-for-fishing-trawler-workers?fbclid=IwAR3kQrJMvZwXx7krfgAu-G0oPWwIlaLBam6dleVKLa6DVUzMb3HuPHDT_0c (Accessed: 6 May 2023).

Trandafir, S. *et al.* (2020) 'How are tourists affected by offshore wind turbines? a case study of the first U.S. offshore.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 68–71

ISSN: 1697-4840, www.jmr.unican.es

Concept of an Electric-Powered Passenger Vessel in Bangladesh

Minhazul Islam[1,*], Saad Alif-A Zaman[1], Md. Mashiur Rahaman[1]

ARTICLE INFO

Article history:
Received 13 May 2023;
in revised from 28 Jun 2023;
accepted 31 Aug 2023.

Keywords:
GHG, diesel engine, electric propulsion, energy efficiency, automation.

ABSTRACT

In Bangladesh, the current trend in shipbuilding relies on diesel engines for propulsion. Unfortunately, these engines produce a significant amount of CO_2 and greenhouse gas emissions, which is a concern both locally and globally. To find a better solution, it is necessary to design waterborne transportation with electric propulsion. Although electric propulsion requires a larger initial investment, it proves to be more cost-effective in the long run compared to diesel-based systems. Electric propulsion is highly efficient, with an energy efficiency of 85%, more than double that of diesel engines. Moreover, electric propulsion systems are compact and lightweight, allowing for an increased payload capacity. Another advantage of electric propulsion is its potential for automation and further development. However, building sufficient infrastructure for electric vessels requires careful consideration in Bangladesh. To explore the economic feasibility, this study focuses on the design of a conceptual electric vessel for inland routes in Bangladesh, accommodating 100 passengers. A cost analysis is conducted to compare the two propulsion systems. By examining the costs involved, this research aims to provide valuable insights into the viability of electric propulsion in Bangladesh's water transportation sector. The findings of this study will contribute to the ongoing discussions on sustainable transportation solutions, particularly for inland waterways in Bangladesh..

1. Introduction.

Inland waterborne transportation has been a key driver of sustainable and advanced economies for centuries, offering a popular means of travel. When designing modern commercial vessels, choosing and optimizing the propulsion system is a critical decision. Currently, diesel engines are commonly used as the propulsion system for new ships. However, the widespread use of diesel engines in waterborne transportation leads to significant emissions of greenhouse gases, including methane and CO_2, which are released into the atmosphere. These emissions result from the consumption of fossil fuels. According to the (Fourth Greenhouse Gas Study 2020, n.d.), the shipping industry accounted for approximately 2.89% of the total global human-related CO_2 emissions in 2018. This amounted to around 1,056 million tonnes of CO_2. It is important to focus on the environmental impact caused by the shipping industry, with the traditional diesel engine being a major contributor to these emissions. Between 2012 and 2019,

According to the website "The Global Economy," the data of Bangladesh experienced a rapid increase in greenhouse gas emissions, in line with the global trend (Bangladesh Economic Indicators | TheGlobalEconomy.Com, n.d.). As both global and local emissions continue to rise, the importance of alternative energy sources, renewable energy, and improved technologies becomes evident. However, regardless of technological advancements in water transportation, if fossil fuels are used as the energy source, CO_2 and greenhouse gas emissions will persist. Bangladesh has committed to reducing greenhouse gas emissions by at least 5% and ideally 15% by 2030, as stated in its nationally determined contribution (NDC Roadmap and Sectoral Action Plan – Nature Conservation Management, n.d.). In order to achieve this target, designing vessels with electric propulsion is essential. The increased power consumption of diesel engines leads to higher fuel consumption and CO_2 emis-

[1]Department of Naval Architecture and Marine Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000.

[*]Corresponding author: Minhazul Islam. E-mail Address: minhazulislam-nazat@gmail.com.

sions, thereby reducing the Energy Efficiency Design Index (EEDI) of the vessels (Karim & Hasan, 2017). In contrast, electric propulsion systems, including motors, batteries, and inverters, do not emit any CO_2, resulting in a zero EEDI for electric ships. Electric vessels offer additional benefits such as a cleaner propulsion space, reduced noise, and vibration. Furthermore, the potential for automation and further development makes electric propulsion highly promising.

2. Design.

2.1. Principal particulars.

The determination of the vessel's principal particulars was carried out using two methods: empirical formulations and corresponding ratios from the book Ship Design Methodologies of Preliminary Design by (Papanikolaou, 2014). For this particular vessel with a passenger capacity of 100, the inland shipping regulations dictate a crew size of 10. To calculate the preliminary weight and displacement, various factors were considered, including the distance and voyage time, the weight of passengers' luggage and belongings, water requirements for drinking, cooking, and washrooms for both passengers and crew, the weight of batteries and electric equipment, reserve water, and cooling water for auxiliary machinery. Through multiple iterations, the dimensions obtained from both methods were converged upon, resulting in the determination of the preliminary principal particulars. These particulars are presented in Table 1.

Table 1: Principal Particular of the vessel.

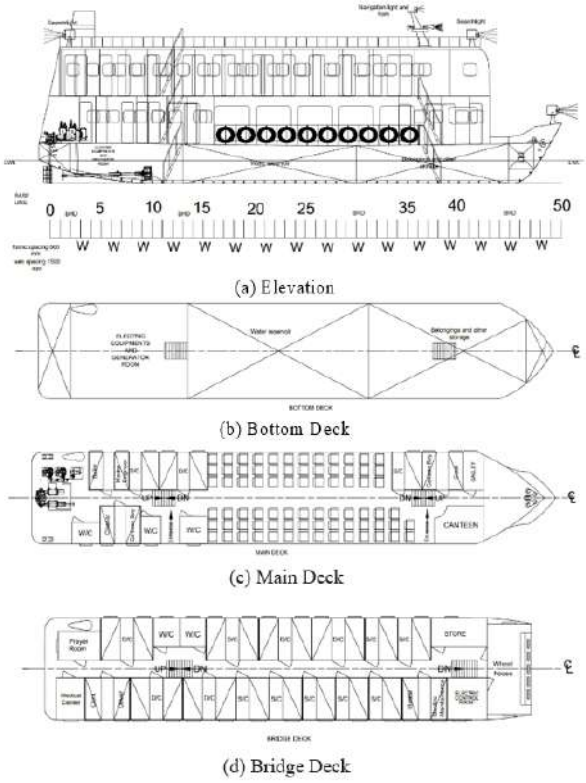
Items	Values
Length Between perpendiculars, L_{bp}	23.8 meter
Length Overall, L_{oa}	25.6 meter
Breadth moulded, B_{mld}	4.5 meter
Design Draft, T	1.12 meter
Displacement	64.7 tonnes
Block Coefficient, C_b	0.52
Service Speed, V	15 knots
Break Power, P_b	260 kW

Source: Authors.

2.2. GA plan, Lines Plan, and Midship Section Drawing.

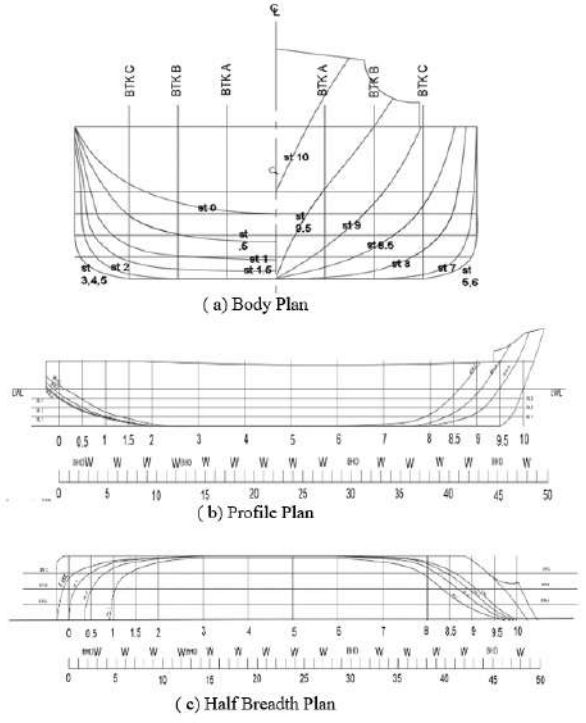
When designing the general arrangement (GA) plan of the vessel, multiple crucial parameters were taken into consideration. The plan needed to ensure sufficient space for passengers while complying with the requirements set by the International Maritime Organization (IMO) and the classification society to ensure optimal comfort and safety. Figure 1 illustrates the general arrangement of the vessel, showcasing the spatial arrangement for various components. In terms of the hull shape, several iterations were conducted to achieve the desired hull coefficients. Figure 2 displays the lines plan of the vessel, providing a visual representation of its hull shape.

Figure 1: General arrangement of the vessel (a, b, c, d).



Source: Authors.

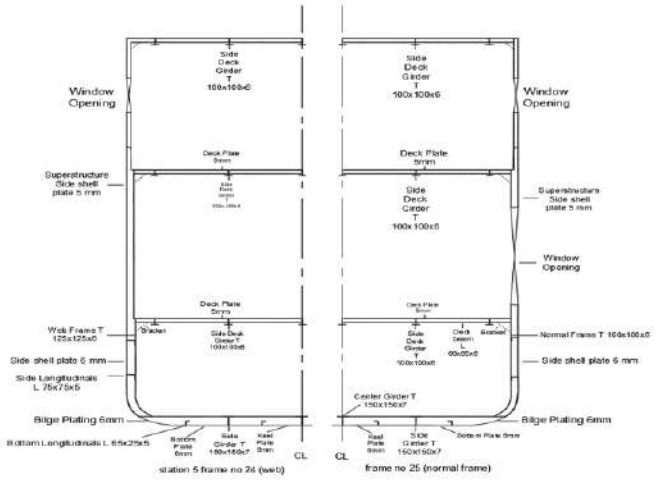
Figure 2: Lines plan of the vessel (a, b, c).



Source: Author.

As the vessel is designed to be operated in inland routes, the scantling of structural components is determined based on the guidelines provided in the rulebook "RULES FOR BUILDING AND CLASSING STEEL VESSELS UNDER 90 METERS (295 FEET) IN LENGTH (2019)". The dimensions of plates and sections are sourced from standard catalogs used in the industry. Figure 3 depicts the midship section of the vessel, providing a visual representation of the structural arrangement.

Figure 3: Midship section of the vessel.



Source: Authors.

2.3. Cost Analysis.

The cost estimation for the propulsion system of the vessel carrying 100 passengers is divided into three parts: battery cost, propulsion machinery cost, and charging infrastructure cost. To meet the requirement of 260-kilowatt brake power, a permanent magnet AC motor is chosen, along with a DC to AC inverter. A battery set capable of delivering power for a 7-hour trip is selected, resulting in a rated battery capacity of 1820 kilowatt-hours with a suitable C-rating. Additionally, other necessary electrical equipment is included. The cost summary for the electric propulsion system is presented in Table 2.

Table 2: Cost summary.

Item	In USD
Battery Cost	2,900
Propulsion machinery cost	17,000
Charging infrastructure cost (Shore charging)	11,75,350
Total	11,95,250

The pricing may vary over time, region, and brand.

Source: Authors.

To provide an approximate cost comparison between conventional diesel engine propulsion and electric propulsion, a 260-kilowatt diesel engine and its gearbox have been selected as a reference for the conventional propulsion system. While electric propulsion requires a larger initial investment, the charging infrastructure needs to be built only once for a port, resulting in potential long-term cost savings. Table 3 presents the approximate cost comparison between two propulsion systems. Furthermore, electric propulsion offers lower maintenance and operating costs, making it a more favorable option over time. A case study comparing an existing electric vessel named "ELLEN" with a diesel vessel and a diesel-electric hybrid vessel, conducted by Abrahamsen in 2020, provides insights into the benefits and outcomes of electric propulsion.

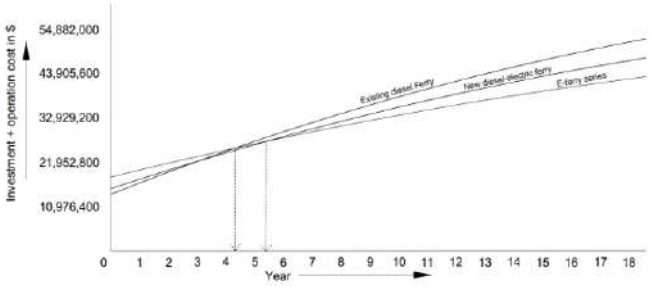
Table 3: Approximate cost comparison.

Item	Diesel Engine Based propulsion (in USD)	Electric propulsion (in USD)
Propulsion machinery cost	15,000	17,000
Battery Cost	--	2,900
Charging Infrastructure	--	11,75,350

Source: Authors.

So, electric propulsion has larger initial investments however the charging infrastructure needs to be built only once for a port. But due to lower maintenance and operating cost, electrical propulsion provides a better outcome in the long run. Figure 4 shows the case study of an existing electric vessel called "ELLEN" with a diesel vessel, and a diesel-electric hybrid vessel (Abrahamsen, 2020).

Figure 4: Cost case study between different types of vessels.



Source: Abrahamsen, 2020.

An important point of discussion is the shift from using diesel oil to electric power in the conceptual electric vessel. As of February 2023, the price of electricity is 7.86 Tk BDT (0.073 USD) per kilowatt-hour, while the price per liter of diesel oil is 109 Tk (1.01 USD) (Retail Power Price: Hiked Again, in Just 3 Weeks - Dhaka Evening, n.d.) (Gasoline and Diesel Prices by Country | GlobalPetrolPrices.Com, n.d.). Considering that

1 liter of diesel oil has the energy equivalent of approximately 10 kilowatt-hours (The Number One Resource for Sustainability in UK Tertiary Education | Sustainability Exchange, n.d.), the corresponding electricity price is 78.6 Tk BDT (0.73 USD), resulting in a cost-saving of 30.4 Tk (0.28 USD) per liter. This makes electric propulsion more cost-efficient. Safety and health considerations are also important. As the vessel is fully electric, fire hazard prevention measures are crucial. Fire detection sensors and a water-cooling system are installed, and vents are constructed for battery gas ventilation from the battery storage to the deck. All crew members are trained in fire prevention and firefighting. The electric vessel offers a safer respiratory environment for the crew, as there is a significant reduction in pollution compared to conventional marine diesel engines. Fully electric vessels have zero emissions and a clean propulsion space, minimizing the risk of respiratory health-related issues for the crew. From a structural standpoint, there is minimal difference between a conventional diesel engine and a fully electric vessel. The weight of steel, wood, and outfitting is similar for both cases. The only difference lies in the machinery weight and the stiffening method. However, through analysis of various electric vessels worldwide, it has been determined that a diesel engine propulsion system capable of delivering a specific amount of brake power weighs more than an electric propulsion system delivering the same power. The reduction in weight allows for increased payload capacity and, subsequently, greater profitability for the vessel owner.

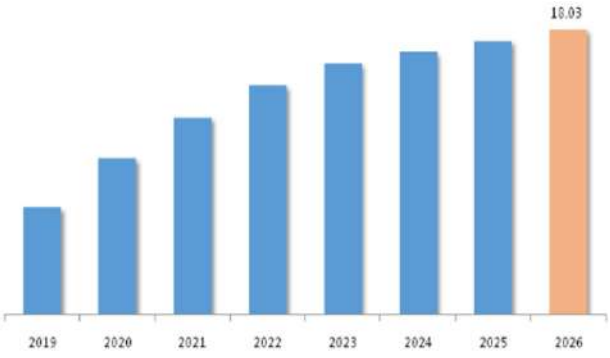
3. Results and Discussion.

Electric propulsion offers several advantages over conventional diesel propulsion. With increasing environmental concerns, the global market for electric ships is expanding significantly. From Figure 5, it is projected that by 2026, the global electric boat market will reach a value of approximately 18.03 billion (Global Electric Boat Market Size, Trend Analysis, Market Competition Scenario & Outlook, 2021-2026, n.d.). The cost of components for electric propulsion systems may vary across different brands and suppliers. Accurate pricing information can be obtained through further data collection, assessment, and inquiries. Additionally, the establishment of a charging infrastructure would require a certain level of funding. Currently, the shipbuilding trend in Bangladesh does not involve electric propulsion. However, if shipbuilders in Bangladesh start showing interest in electric vessels, it would greatly enhance the scope of this study. As the world increasingly adopts eco-friendly solutions, electric shipbuilding emerges as a viable option.

Conclusions

The cost-benefit analysis of electric propulsion, utilizing a conceptual vessel designed to accommodate 100 passengers, demonstrates the advantages of choosing an electric propulsion system over a conventional diesel-based system. Despite the numerous benefits offered by electric propulsion, the feasibility of its implementation in Bangladesh is hindered by the lack of interest in electric shipbuilding within the country. However, on a global scale, the electric shipbuilding market is experiencing rapid growth. Encouraging shipbuilding industries in Bangladesh to adopt electric propulsion can yield substantial economic and environmental benefits for the country.

Figure 5: Global electric boat market analysis (USD in Billions).



Source: BlueWeave Consulting.

References.

Abrahamsen, H. (2020). Ensuring efficiency and safety in electric vessels Ensuring efficiency and safety in electric vessels Evaluating the E-ferry systems and safety measures.

Bangladesh Economic Indicators (no date) TheGlobalEconomy.com. Available at: https://www.theglobaleconomy.com/Bangladesh/ (Accessed: 13 May 2023).

Fourth Greenhouse Gas Study 2020 (no date) International Maritime Organization. Available at: https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx (Accessed: 13 May 2023).

Gasoline and diesel prices by country | GlobalPetrolPrices.com. (n.d.). Retrieved May 13, 2023, from https://www.globalpetrolprices.com/.

Global Electric Boat Market Size, Trend Analysis, Market Competition Scenario & Outlook, 2021-2026. (n.d.). Retrieved May 13, 2023, from https://www.blueweaveconsulting.com/report/global-electric-boat-market-bwc20131.

Karim, M.M. and Hasan, S.R., 2017. Establishment of EEDI baseline for inland ship of Bangladesh. Procedia engineering, 194, pp.370-377.

NDC Roadmap and Sectoral Action Plan (no date) Podgorica. Available at: https://nacom.org/document/ndc-roadmap-and-sectoral-action-plan/ (Accessed: 13 May 2023).

Papanikolaou, A., 2014. Ship design: methodologies of preliminary design. Springer.

Retail power price: Hiked again, in just 3 weeks - Dhaka Evening. (n.d.). Retrieved May 13, 2023, from https://dhakaevening.com/energy/retail-power-price-hiked-again-in-just-3-weeks/.

The number one resource for sustainability in UK tertiary education | Sustainability Exchange. (n.d.). Retrieved May 13, 2023, from https://www.sustainabilityexchange.ac.uk/home.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 72–80

ISSN: 1697-4840, www.jmr.unican.es

Blockchain Implementation Barriers in Maritime: A Case Study based on ISM and MICMAC Techniques

Sanja Bauk[1,*], Lindani Handsome Ntshangase[2]

ARTICLE INFO

Article history:
Received 15 May 2023;
in revised from 28 Jun 2023;
accepted 31 Jul 2023.

Keywords:
maritime, blockchain, barriers, assessment, ISM, MICMAC.

ABSTRACT

This article considers blockchain implementation and adoption in maritime sector, including its benefits and challenges. In addition to a review of existing literature sources in this domain, through a case study the impediments of deploying blockchain in a developing maritime environment are examined. The analysis are based on the Interpretative Structural Modeling (ISM) and Cross-Impact Matrix Multiplication Applied Classification (MICMAC) methods. In this context, it is to be pointed out that the constraints in blockchain mainstream adoption in maritime are explored in several comprehensive academic papers so far. The same applies for ISM and MICMAC approaches. Therefore, in the focus of this work is a case study conducted among the specialists in maritime industry, business and higher education in South Africa as an emerging maritime ecosystem. The subjectivity inherent to the applied methodology is highlighted, since different specialist can differently evaluate pairwise relationships among the considered constraints..

1. Introduction.

Maritime sector has the smallest innovation impact in comparison to other industries, since it is profit-driven and conservative [1]. Even though ports and shipping logistics play an essential role in global supply chains, the successful innovation path should include larger number of stakeholders intertwined into maritime. The increased global demand for commodities, increased the need for sea transportation of freight containers. The massification of maritime transport led to evolved business clusters, but these are mostly fragmented into modular centralized systems [2]. Sea ports serve as central hubs for these clusters at a globally spread shipping market. Consequently, port community systems (PCSs) were introduced as unifying platforms to facilitate needs of numerous actors. Commonly, PSCs enable streamlined data exchange and trading processes, simplified alignment with international standards, and set the founding stone for processes automation. It is difficult to generalize the exact functionalities of PCSs because they vary depending on the community's players and their relevant metrics [3]. Regardless of this, PCSs allow better business compliance, improved security, and decrease in fraudulent activities [4]. PCSs were a setting stone in the digitization in maritime. Next milestone was the introduction of maritime single window (SW) environment [5]. SW is a synonym for a single point interaction between maritime affairs and authorities. PCSs and SWs can bring great benefits on a local scale, while fragmentation and the lack of reliable real-time data on a global scale are still present [6]. Therefore, blockchain brings a quantum leap for the maritime sector with the potential to enable transition from globally fragmented centralized systems to a peer-to-peer network, without the need for complete trust between actors. Transactions can be done through the distributed, append-only digital registry or ledger that is constantly maintained through consensus mechanisms and protected by asymmetric cryptography algorithms. As a decentralized system, blockchain eliminates a single point of failure and the need for trusted inter-

[1]Estonian Maritime Academy. Tallinn University of Technology, Estonia. Email: bsanjaster@gmail.com; sanja.bauk@taltech.ee

[2]Faculty of Applied Sciences, Maritime Studies Department. Durban University of Technology, South Africa. Email: lindanin3@dut.ac.za

[*]Corresponding author: Sanja Bauk. E-mail Address: bsanjaster@gmail.com; sanja.bauk@taltech.ee.

mediaries. Due to some predictions, it can facilitate the improvement and growth in world trade of 15% [7], along with the reduction of transportation costs of 20% [8]. Through smart contracts, as a part of blockchain technology, personalized automated services can increase, along with an achievable 40% decrease in delivery delays [9]. This supports the hypothesis that blockchain can be used in maritime sector for seamless operational processing including higher level of digitization and efficiency.

Having in mind still unrelieved maritime blockchain integration potentials, *Section 2* gives its overview, including its pros and cons; *Section 3* deals with the case study based on ISM and MICMAC techniques for establishing hierarchy and determining the nature of relations among the considered barriers in its wider adoption; *Section 4* gives data analysis results; while *Section 5* contains conclusion, along with the recommendations for further research. This paper is a follow up of the papers [10;11] and it includes extended literature review and the analysis carried out on the larger group of interviewed specialists.

2. Blockchain in maritime.

Maritime blockchain serves ports and shipping logistics. It includes cargo tracking and tracing, automation of port terminal operations, protection of trade documentation, assets certification, crew certificates of competences, fleet operation management, empty containers optimal placement, payments, and the like [12]. It offers a foundation for faster, easier, more efficient, and lower-cost trade-related operations. It supports collaborative commerce by allowing licensed parties to access the trusted data in real time [13]. Albeit, maritime blockchain can be organized as a hybrid network that includes clusters of public, private and consortium bodies [14;15;16].

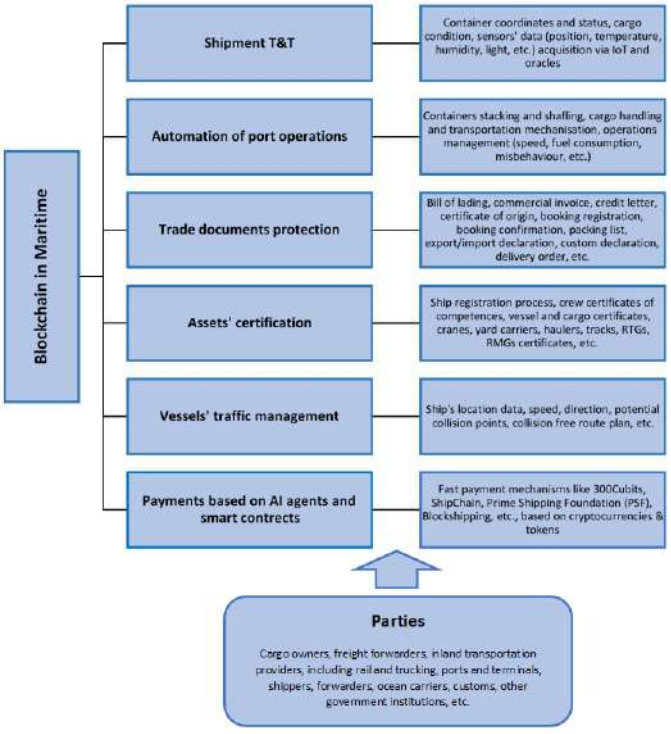
Shipping and port management involve several organizations, which have to ensure efficient flow of shipments from exporter to consignee. As complex and dynamic systems, maritime supply chains generate large amount of data on shipments, port operations, finance, and law regulations. Blockchain technology can play a key role in ensuring trust, security, traceability, and transparency to maritime operations [17]. It has a potential to eliminate frauds related to documentation involved in data and fleet management, trade documentation, crew certification, and shipment tracking. This can increase transaction efficiency and trust among the stakeholders. Blockchain requires every stakeholder involved to register on the permissioned platform. The authorized stakeholders can access the ledger in real time to view the records on the location of the shipment and state of the freight to efficiently plan for cargo handling and terminal operations. After containers are successfully loaded on the shipment vessel, smart contracts can inform the shipment details to various entities such as agents, ship owner, custom officers, and sea traffic police for higher coordination and security. The sensors attached to the containers can assist to identify any illegal attempts that may disrupt the state of cargo inside the container. Such acts will be recorded, audited, and notified to the exporter, port authority, and custom agency through suitable functions within the smart contracts. Furthermore, smart contracts can be programmed to compare the internal state of the container in terms of temperature, humidity, pressure, light and other relevant parameters with preset values, and to trigger alarms in the case of need. This is very useful when it comes to shipments as dangerous cargo, food, pharmaceuticals, etc.

Tracking the location of a vessel can help the port terminal authorities to prepare an optimal stowage plan and to increase the productivity. By using smart contracts, blockchain can efficiently shuffle the containers at the yard terminal and increase resource usage [18]. Additionally, smart contracts can optimize routes of vehicles like straddle carriers' via the agents installed at container yards, by controlling speed, reducing congestion and eventual misbehaving. Consequently, the accidents can be prevented. Besides its roles in cargo tracking and tracing and fleet management, blockchain is a ledger that assures a real-time accessing of trade documents by the participating stakeholders. For instance, it is mandatory for shipping carriers to retain the declaration form during the shipment of hazardous goods. Similarly, the certificate of fitness has to state whether a ship is worthy to perform a journey or not [19]. These documents can be secured on a permissioned blockchain platform (Figure 1).

Maritime blockchain can incorporate smart payment mechanisms as 300Cubits, ShipChain, and Prime Shipping Foundation (PSF), e.g., which are based on crypto-currencies [20]. However, there are still significant barriers and challenges to use blockchain and smart contracts in validating shipments and payments in maritime. The port and shipping industry increasingly faces cybersecurity threats, such as, for instance, the NetPetya ransomware attack that affected Maersk in 2017, at an estimated cost of $200 million in bitcoins [21].

How blockchain based payment practically works in maritime, it can be easily explained at the example of Blockshipping platform, which is developed for empty containers optimal placement [22]. The processes flow within Blockshipping is based on several simple and fully automated steps. The easiest way to make an explanation is to follow an example [23]. Let us assume that shipping line needs to rent a container to transport goods from Nairobi (Kenya) to Rotterdam (Netherlands). Blockshipping empty container repository engine identifies the best-positioned empty container in Nairobi and informs the shipping line about the options. The shipping line informs its autonomous intelligent software agents (AISAs) about the containers. The rental negotiations then happen unsupervised between the shipping line and the container owner through the AISAs. The agreements established are persisted on blockchain in smart contracts that govern the rental. Blockshipping container platform tokens (CPTs) are used to pay rental fees, while the fees are transferred from the shipping line wallet, in accordance to the smart contract and reserved payment. When the container reaches its final destination in Rotterdam, then blockchain enforces the smart contract. The rental ends and releases CPTs to the container owner wallet. The smart contracts can be smoothly changed if conditions change.

Figure 1: Blockchain in maritime: Prospective applications and key parties.



Source: Authors.

Since maritime blockchain generates huge number of transactions, public Bitcoin and Etheraum blockchain platforms are not recommendable as suitable. Bitcoin can provide seven transactions per second [24], while Etheraum performs about twenty transactions per second [25]. Therefore, private Hyperledger Fabric, Besu, and Quorum platforms are more convenient. These platforms can process several hundred transactions per second [26]. Nevertheless, the entire process of maritime blockchain wider adoption is risky and requires a great deal of capital investment [27]. Maritime blockchain rational deployment is still in its infancy, and requires systematic technology testing, standardization and promotion. Stakeholders' awareness and knowledge about this groundbreaking technology should be uplifted, assuming their readiness to share business information and ultimately allow wider blockchain adoption.

2.1. Classification & Types of Mobile Satellite Antennas (MSA).

Even though blockchain has a potential for increasing efficiency and safety of maritime business, there are still numerous barriers in its mainstream implementation. Maritime sector is generally risk averse, tending not to be an early adapter in terms of new technology [28]. Some stakeholders like to preserve their data secret, since competition is fierce and numerous players compete with the same service [29]. Therefore, they consider information as a competitive advantage and do not want to share it along the supply chain. Furthermore, the use of blockchain in maritime does not guarantee that the information recorded into the ledger is correct. For instance, the content of a container, type of fuel used for ship propulsion, data on exhausted gases emission, and the like, might be incorrectly entered into the ledger. In other words, if blockchain-based application record sensors' entry, and the sensors are compromised, the wrong data will be recorded into the ledger [30].

Large amount of data and traffic generated in blockchain need wideband channels like 5G or 6G [31], while the internet speed and stability at sea are usually lower than ashore. Additionally, blockchain technology is high-energy consuming and causes a high carbon footprint [32].

Regardless of maritime blockchain huge potential to reduce administrative and transaction costs of intermediaries such as banks, brokers and courier services, the investment costs are high, especially for developing countries [33;34]. Present level of awareness, knowledge, and expertise on blockchain is scarce among the stakeholders. Therefore, special educational, training and capacity building programs are required at regulatory, administrative and operational levels. Additionally, the major ports and shipping companies are the most likely actors to benefit from blockchain that can put other potential players at a disadvantage [35].

Different attitudes toward cryptocurrency and the absence of a worldwide regulation are the challenges for blockchain more intensive implementation. Cryptocurrencies have been the subject of hacking attacks based on vulnerabilities in apps, software, protocols, smart contracts, and other points of failure where considerable amounts of money were stolen [36].

The last but not the least, the basic attitude should be that blockchain improve the human condition, not replace humans [37]. Therefore, human and ethical dimensions of blockchain technology implementation need further investigation..

3. Methodology.

The case study for collecting information on blockchain adoption in maritime environment has been used as a research design strategy. As a data gathering method, an expert panel was arranged. The criteria for a qualification as an expert are many and varied, but commonly the expert panel comprises independent specialists [38], recognized in maritime sector and its digital transformation. The experts involved into this case study came from maritime industry, business, and higher maritime education and training institutions in South Africa (more precisely, from Cape Town, Durban, Port Elisabeth, Richards Bay, and Saldanha). The assessments of fifty selected experts are taken into consideration. The final matrix of barriers' pairwise comparisons is obtained by taking into account the frequency of certain denominators appearances in the individual experts' assessments. This was one-time study, since the data are gathered only once. Collected experts' individual evaluations are edited, coded and analyzed through ISM and MICMAC techniques, which are described in the following two subsections.

3.1. The ISM technique.

The ISM is a well-structured, collaborative technique to reveal the relationships and hierarchy between considered barriers in the model [39;40;41;42]. It transforms initially unclear

and poorly articulated interpretations into a visible and well-defined structural scheme. Firstly, a set of maritime blockchain implementation barriers has to be identified. Then, an aspect has to be added to the contextual relationships, for instance, does barrier B1 affect barrier B2, or vice versa, or they mutually affect each other, or there is no relationship between them. After the barriers and contextual framework are determined, each member of the experts' panel has to perform pairwise comparisons. The transitivity of the contextual relationship is a fundamental assumption in the ISM. It states that if barrier B1 is related to B2, and B2 is related to B3, than B1 is necessarily related to B3. This enables creation of a final reachability matrix and a hierarchical structural model.

3.2. The MICMAC technique.

The MICMAC means creating a graph that classifies barriers in the model according to their driving and dependence powers [43;44;45;46]. It enables the study of indirect relationships, and it is known as a gray area exploration. More precisely, it complements the ISM approach, which explores the relationships yes/1 or no/0, and neglects the gray area between these two. This is where the MICMAC can assist in establishing clearer picture of the barriers relations, including driving and dependence levels presented into the form of a graph.

4. The analysis.

The extensive research on barriers in blockchain implementation in maritime presented in [47], along with our previous studies [10;11], are used as a base for the extended analysis presented in this article, while a large group of fifty specialist in maritime (from South Africa) assessed the following maritime blockchain implementation barriers:

- Barrier 1: Lack of government blockchain regulations;
- Barrier 2: Lack of trust in blockchain;
- Barrier 3: Actors' reluctance to share business information;
- Barrier 4: Lack of knowledge and understanding of blockchain;
- Barrier 5: Lack of support from stakeholders;
- Barrier 6: Stakeholders' reluctance to adopt blockchain;
- Barrier 7: High investment costs;
- Barrier 8: Lack of early adopters in maritime.

Barriers' indexes 1 to 8 correspond to both i and j, while i always precedes j in pairwise comparisons of the barriers. Pairs of identified barriers are compared by means of the following denominators:

- F: barrier i leads to barrier j ($i \rightarrow j$);
- R: barrier j lead to barrier i ($j \rightarrow i$);
- FR: barrier i leads to barrier j, and vice versa ($i \leftrightarrow j$); and
- X: barrier i and j are unrelated ($i \neq j$).

Respondents were asked, individually, to compare pair-by-pair barriers in the model. The value F, R, FR, or X with the highest frequency of appearances (Max. Freq.) in the individual experts' matrixes (Table 1) is selected and inserted into the appropriate field of the structural self-interaction matrix (Table 2).

Table 1: The respondents' barriers pairwise assessments.

	F	R	FR	X	Max. Freq.
B1-B2	41	0	4	5	F
B1-B3	25	6	0	19	F
B1-B4	9	6	3	32	X
B1-B5	27	8	8	7	F
B1-B6	24	7	4	15	F
B1-B7	14	5	4	27	X
B1-B8	16	14	6	14	F
B2-B3	21	12	13	4	F
B2-B4	11	14	19	6	FR
B2-B5	19	13	8	10	F
B2-B6	22	4	8	16	F
B2-B7	20	5	1	24	X
B2-B8	19	10	6	15	F
B3-B4	18	13	4	15	F
B3-B5	14	12	8	16	X
B3-B6	15	10	11	14	F
B3-B7	3	11	4	32	X
B3-B8	12	14	9	15	X
B4-B5	25	6	13	6	F
B4-B6	14	11	14	11	FR
B4-B7	14	7	2	27	X
B4-B8	17	8	12	13	F
B5-B6	23	11	12	4	F
B5-B7	19	11	6	14	X
B5-B8	15	12	9	14	F
B6-B7	12	9	16	13	FR
B6-B8	19	9	15	7	F
B7-B8	16	4	7	23	X

Source: Authors.

The structural self-interaction matrix (Table 2) is converted into a binary one, called the initial reachability matrix by sub-

Table 2: Structural self-interaction matrix.

	B1	B2	B3	B4	B5	B6	B7	B8
B1	FR	F	F	X	F	F	X	F
B2	R	FR	F	FR	F	F	X	F
B3	R	R	FR	F	X	F	X	X
B4	X	FR	R	FR	F	FR	X	F
B5	R	R	X	R	FR	F	X	F
B6	R	R	R	FR	R	FR	FR	F
B7	X	X	X	X	X	FR	FR	X
B8	R	R	X	R	R	R	X	FR

Source: Authors.

stituting F, R, FR, and X with 0 and 1 in correspondence to the scheme given in Table 3.

Table 3: Conversion scheme.

	(i, j)	(j, i)
F	1	0
R	0	1
FR	1	1
X	0	0

Source: Authors.

In accordance with the data presented in Table 2 and the scheme given in Table 3, the initial reachability matrix is formed (Table 4).

This initial reachability matrix shows only the direct relationships among the barriers. To include indirect relationships, the transitivity principle is applied. Transitivity means that when B1 is related to B2, and B2 is related to B3, then definitely B1 is related to B3. This is obtained by multiplying the initial reachability matrix by itself until it became stabilized. The multiplication is performed using Boolean matrix multiplication defined by the equation (1):

$$(AB)_{ij} = \cup_{k=1}^{n} = (A_{ik} \cap B_{kj}) \tag{1}$$

The process of multiplying the initial reachability matrix twice by itself is presented through the following steps (Step 1 & 2):

Table 4: Initial reachability matrix .

	B1	B2	B3	B4	B5	B6	B7	B8
B1	1	1	1	0	1	1	0	1
B2	0	1	1	1	1	1	0	1
B3	0	0	1	1	0	1	0	0
B4	0	1	0	1	1	1	0	1
B5	0	0	0	0	1	1	0	1
B6	0	0	0	1	0	1	1	1
B7	0	0	0	0	0	1	1	0
B8	0	0	0	0	0	0	0	1

Source: Authors.

Step 1

$$\begin{vmatrix} 1&1&1&0&1&1&0&1&1\\ 0&1&1&1&1&1&0&1&0\\ 0&0&1&1&0&1&0&0&0\\ 0&1&0&1&1&1&0&1&0\\ +0&0&0&0&1&1&0&1&0\\ 0&0&0&1&0&1&1&1&0\\ 0&0&0&0&0&1&1&0&0\\ 0&0&0&0&0&0&0&1&0 \end{vmatrix} \cap \begin{vmatrix} 1&1&1&0&1&1&0&1&1\\ 0&1&1&1&1&1&0&1&0\\ 0&0&1&1&0&1&0&0&0\\ 0&1&0&1&1&1&0&1&0\\ 0&0&0&0&1&1&0&1&0\\ 0&0&0&1&0&1&1&1&0\\ 0&0&0&0&0&1&1&0&0\\ 0&0&0&0&0&0&0&1&0 \end{vmatrix} =$$

Step 2

$$= \begin{vmatrix} 1&1&1&1&1&1&1&1&1\\ 0&1&1&1&1&1&1&1&0\\ 0&1&1&1&1&1&1&1&0\\ 0&1&1&1&1&1&1&1&0\\ 0&0&0&1&1&1&1&1&0\\ 0&1&0&1&1&1&1&1&0\\ 0&0&0&1&0&1&1&1&0\\ 0&0&0&0&0&0&0&1&0 \end{vmatrix} \cap \begin{vmatrix} 1&1&1&0&1&1&0&1&1\\ 0&1&1&1&1&1&0&1&0\\ 0&0&1&1&0&1&0&0&0\\ 0&1&0&1&1&1&0&1&0\\ 0&0&0&0&1&1&0&1&0\\ 0&0&0&1&0&1&1&1&0\\ 0&0&0&0&0&1&1&0&0\\ 0&0&0&0&0&0&0&1&0 \end{vmatrix} =$$

$$= \begin{vmatrix} 1&1&1&1&1&1&1&1&1\\ 0&1&1&1&1&1&1&1&0\\ 0&1&1&1&1&1&1&1&0\\ 0&1&1&1&1&1&1&1&0\\ 0&1&0&1&1&1&1&1&0\\ 0&1&1&1&1&1&1&1&0\\ 0&1&0&1&1&1&1&1&0\\ 0&0&0&0&0&0&0&1&0 \end{vmatrix}.$$

The final reachability matrix is given in Table 5, along with the values of the driving power (DRP) and dependence power (DNP), which are calculated by equations (2) and (3):

$$Driving\_power(DRP) : \sum_{j=1}^{8} b1\,j \tag{2}$$

$$Dependence\_power(DNP) : \sum_{i=1}^{8} bi1 \tag{3}$$

Based on the final reachability matrix, reachability set of nodes for each barrier can be identified, as well as the set of ascendant nodes and the intersection sets (Table 6). Through the iterative process, equality of ascendant and intersections sets is examined, by eliminated elements from these two sets that are equal and continuing the process until all barriers are covered and associated with the appropriate level of hierarchical structure. The iterative process starts with the barriers for which ascendant and intersection elements are the same.

Table 5: The final reachability matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	[DRP]
B1	1	1	1	1	1	1	1	1	8
B2	0	1	1	1	1	1	1	1	7
B3	0	1	1	1	1	1	1	1	7
B4	0	1	1	1	1	1	1	1	7
B5	0	1	0	1	1	1	1	1	6
B6	0	1	1	1	1	1	1	1	7
B7	0	1	0	1	1	1	1	1	6
B8	0	0	0	0	0	0	0	1	1
[DNP]	1	7	5	7	7	7	7	8	

Legend: [DNP] – dependence power & [DRP] driving power.
Source: Authors.

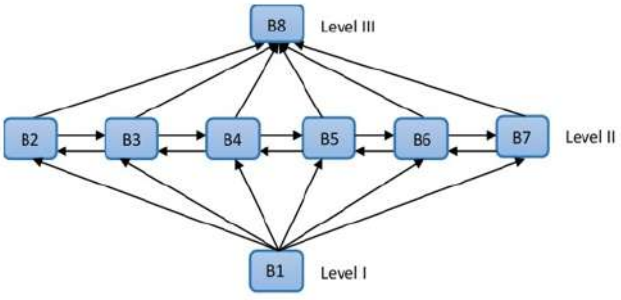
Table 6: The barriers hierarchical level identification.

	Reachability set	Antecedent set	Intersection set	Iteration	Level
B1	1,2,3,4,5,6,7,8	1	1	1	I
B2	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,3,4,5,6,7	2	II
B3	2,3,4,5,6,7,8	1,2,3,4,6	2,3,4,6	2	II
B4	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,3,4,5,6,7	2	II
B5	2,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B6	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B7	2,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B8	8	1,2,3,4,5,6,7,8	8	3	III

Source: Authors.

The results given in Table 6 enabled creation of the ISM hierarchical scheme (Figure 2).

Figure 2: The ISM hierarchical scheme of the maritime blockchain adoption barriers.

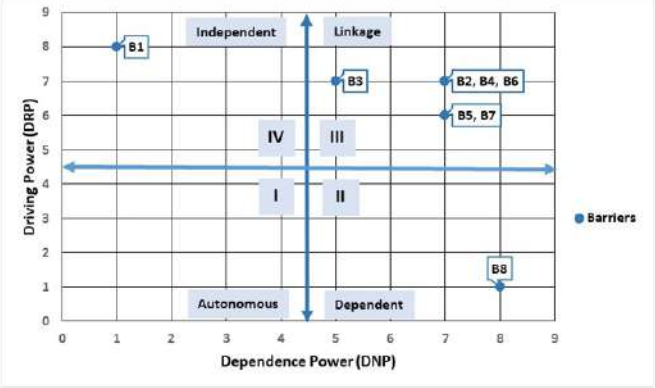


Source: Authors.

In addition to the ISM analysis, MICMAC approach has been applied. The first step in conducting MICMAC technique is to determine the dependence power (DNP) and driving power (DRP) of each considered barrier (Table 5). The dependence power is determined by adding all the values in column j of the final reachability matrix. Meanwhile, the driving power of a variable is determined by adding all the values in row i of the final reachability matrix. The results of this examination are given in Figure 3. The driver – dependency diagram is divided into four quadrants, while X-axis presents dependency power, and Y-axis shows driving power. From the diagram, the following can be observed:

- Quadrant I contains no barriers.
- Quadrant II contains B8 barrier, which means that it depends on other barriers, what confirms the ISM hierarchical scheme.
- Quadrant III contains six barriers B2, B3, B4, B5, B6 and B7. These barriers are so-called linkage barriers. These require careful analysis, since they can cause domino effect and breakdown of other barriers due to the high number of interconnections.
- Quadrant IV contains B1 barrier. This independent barrier requires careful consideration, since it is the root cause of all other barriers in the model. It may help to remove other barriers. It is placed at the bottom levels of ISM hierarchical diagram.

Figure 3: The MICMAC diagram of the maritime blockchain wider adoption barriers.



Source: Authors.

The results of ISM and MICMAC give a better insight into the connections among the limitations while implementing blockchain in maritime. However, it should be emphasized that the obtained results largely depend on the knowledge, experience, and perception of the respondents and that they can be significantly different if the structure of the experts' panel changes. Besides, the statistical generalizability is very restricted in the case study approach, in general [48]. This is the limitation of the applied methodology, but it can provide at least an idea of

interdependence of the factors that inhibit faster implementation of a groundbreaking blockchain technology and its principles.

Conclusions

This work points to the potential benefits and challenges of wider application of blockchain in maritime sector. Beside, its focus is structuring of the barriers in blockchain implementation in an emerging maritime environment. Namely, through the case study conducted among the experts in maritime industry, business and education in South Africa, the paper equips decision makers with understanding of how ISM and MICMAC techniques can assist in interpreting relationships among the barriers in blockchain wider adoption. The applied methodology can assists professionals to develop strategies to mitigate the constraints inherent to the complex and intertwined maritime environment and new technology deployment. The task of the analyzed group decision-making model is to give the highest priority to the barrier at the bottom of the ISM hierarchical scheme, since it drives other barriers in the model. In the analyzed case this is the lack of government regulations regarding blockchain technology and its implementation. According to the applied MICMAC technique, the lack of government regulations is the independent barrier with a high driving power and low dependent one. At the second level of the ISM hierarchal scheme are the following barriers: the reluctance of stakeholders to share business information, the lack of knowledge and understanding of blockchain technology, the lack of support from stakeholders, the stakeholders' reluctance to adopt blockchain, and relatively high investment costs. In relation to the MICMAC, these barriers are linkage ones. They are linked mutually and link all other barriers in the model, and as such, they can cause so-called domino effect. At the top of the ISM pyramidal scheme, there is the lack of early new technology adopters in maritime. This means that all other barriers in the considered model affect this constraint. The lack of early adopters in maritime is therefore the dependent variable in the considered case, with high dependent and low driving power. Finally, we have to highlight that researchers have to be aware of the subjectivity of the assessments of the experts' individual pairwise comparisons of maritime blockchain wide deployment impediments. This consequently requires a careful selection of the experts who are supposed to make assessments. They should have long lasting experience in maritime, as well as a high level of logical and critical thinking skills in order to ensure credibility of such a group decision-making process. In future studies, the number of involved interviewees should be larger, so that we can better explain the aspects of blockchain better integration into shipping and port logistics.

Acknowledgements.

The research was supported by the EU Horizon2020 project MariCybERA, Agreement no. 952360.

References.

[1] J. P. Rodrigue (2010). Maritime transportation: Drivers for the shipping and port industries. Proceedings of the International Transport Forum, Leipzig, Germany, 26-28 May 2010, pp. 1-21.

[2] R. Abdallah et al. (2023). Assessing Blockchain Challenges in Maritime Sector. Proceedings of the Blockchain and Applications, 4^{th} International Congress, L'Aquila, Italy, 12-14 July 2022; Springer: Berlin/Heilderberg, Germany, 2023; pp. 13-22.

[3] D. Desiderio (2011). Port community systems, customs one-stop-shops and their possible combination with a single window. Journal of Customs and Trade 2011, 3, pp. 3-14.

[4] IPCSA – International Port Community System (n.d.). Port Community System – General. Retrieved from: https://ipcsa.international/pcs/pcs-general/

[5] I. Koliousis, P. Koliousis, T. Katsoulakos (2015). Maritime Single Window: Lessons learned from the eMAR Project. In Ehlers et al. (Eds.), Maritime-Port Technology and Development, Taylor & Francis Group, London, UK.

[6] T. Jensen, N. Bjorn-Andersen, R. Vatrapu (2014). Avocados crossing borders. Proceedings of the 5^{th} ACM International Conference on Collaboration across Boundaries: Culture, Distance Technology, Kyoto, Japan, 20-22 August 2014; ACM Press: New York, NY, USA, pp. 15-24.

[7] WEF - World Economic Forum (2013). Enabling Trade Valuing Growth Opportunities. Retrieved from: https://www3.weforum.org/docs/WEF_SCT_EnablingTrade_Report_2013.pdf

[8] S. Wang, X. Qu (2019). Blockchain applications in shipping, transportation, logistics, and supply chain. In Smart Transportation Systems 2019; Springer: Berlin/Heilderberg, Germany, pp. 225-231.

[9] T. Jensen, J. Hedman, S. Henningsson (2019). How tradelens delivers business value with blockchain technology. MIS Quarterly Executive, 18, pp. 221-243.

[10] S. Bauk (2023). Analysis of Barriers in Maritime Blockchain Implementation. High Technology Letters, Vol. 29, No. 4, pp. 113-125.

[11] S. Bauk, L. H. Ntshangase (2023). Maritime Blockchain Constraints? Analysis by ISM and MICMAC Techniques. Proceedings of the 12th Mediterranean Conference on Embedded Computing (MECO), Budva, Montenegro, 6-10 June 2023, DOI: 10.1109/MECO58584.2023.10155037.

[12] R. W. Ahmad, et al. (2021). Blockchain applications and architectures for port operations and logistics management, Research in Transportation Business & Management, 41, 100620. DOI: https://doi.org/10.1016/j.rtbm.2021.100620

[13] Y. Chen, B. Yang (2022). Analysis on the evaluation of shipping logistics service supply chain market structure under the application of blockchain technology, Advanced Engineering Informatics, 53, 101714. DOI: https://doi.org/10.1016/j.aei-.2022.101714.

[14] E. Ganne (2018). Can Blockchain Revolutionize International Trade, World Trade Organization: Geneva, Switzerland.

[15] N. Botton (2018). Blockchain and trade: Not a fix for Brexit, but could revolutionize global value chains (if govern-

ments let it). In ECIPE Policy Brief 1/2018; European Centre for International Political Economy: Brussels, Belgium.

[16] O. Dib, K. Toumi (2020). Decentralized identity systems: Architecture, challenges, solutions and future directions. Annals of Emerging Technologies in Computing (AETiC), Vol. 4, No. 5, pp. 19-40. DOI: 10.33166/AETiC.2020.05.002

[17] S. Bauk (2020). Blockchain conceptual framework in shipping and port management. Proceedings of the 9th International Conference on Maritime Transport, Bacelona, Spain, 27-29 June 2022. DOI: https://doi.org/10.5821/mt.10848

[18] K. Salah et al. (2019). Blockchain for AI: Review and open research challenges. IEEE Access, 7, pp. 10127-10149.

[19] O. H. Arican et al. (2020). Transportation of chemical cargo by tanker ships. In Handbook of Research on the Applications of International Transportation and Logistics for World Trade. IGI Global, pp. 288-309. DOI: 10.4018/978-1-7998-13-97-2.ch016

[20] E. H. Green et al. (2020 June). Blockchain Technology and Maritime Shipping: An Exploration of Use Cases in the U.S. Maritime Transportation Sector. Retrieved from: https://www.-maritime.dot.gov/sites/marad.dot.gov/files/2020-07/Blockchain-%20Use%20Cases%20Final%20Report%20%2820200622%2-9.pdf

[21] L. Mathews (2017 August 16). NetPetya Ransomware Attack Cost Shipping Giant Maersk Over $200 Million. Retrieved from: https://www.forbes.com/sites/leemathews/2017/08/16/not-petya-ransomware-attack-cost-shipping-giant-maersk-over-200-million/?sh=5a59b48b4f9a

[22] Blockshipping GSCP (2018 June 14). Just in Time Containers. Video file. Retrieved from: https://www.youtube.com/-watch?v=BUas6vfWLeo&t=85s

[23] Blockshipping GSCP (2018 June 14). The GSCP flow. Video file. Retrieved from: https://www.youtube.com/watch?v=-kMV0A-L-dMw&t=89s

[24] R. Bohme et al. (2015). Bitcoin: Economics, technology, and governance. Journal of Economic Perspectives, 29(2), pp. 213-238.

[25] G. Wood et al. (2014). Ethereum: A secure decentralized generalized transaction ledger. Ethereum Project Yellow Paper, 151(2014), pp. 1-32.

[26] S. Pongnumkul et al. (2017). Performance analysis of private blockchain platforms in varying workloads. In 2017 26th International Conference on Computer Communication and Networks (ICCCN), IEEE, pp. 1-6.

[27] A. Torbica, G. Cappellaro (2010). Uptake and diffusion of medical technology innovation in Europe: what role for funding and procurement policies? Journal of Medical Marketing: Device, Diagnostic and Pharmaceutical Marketing, 10(1), pp. 61-69.

[28] A. H. Gausdal, K. V. Czachorowski, M. V. Solesvik (2018). Applying Blockchain Technology: Evidence from Norwegian Companies. Sustainability, 10, 1985. DOI: 10.3390/su10061985.

[29] J. Ytterstrom, L. Lengerg (2019). What role will blockchain play within the maritime shipping industry in five years? University of Gothenburg, School of Business, Economics and Law. Master Thesis. Gothenberg, Sweden. Retrieved from: https://pdfs-.semanticscholar.org/b6d7/cf06c4853ef1745ab4dd12f65f3cc7f-5bcb2.pdf.

[30] A. Reyna et al. (2018). On blockchain and its integration with IoT. Challenges and opportunities. Future Generation Computer Systems, 88, pp. 173-190.

[31] P. Bhattacharya et al. (2021). Coalition of 6G and Blockchain in AR/VR Space: Challenges and Future Directions. IEEE Access, 9: 168455-84. DOI: 10.1109/ACCESS.2021.3136860.

[32] S. Bauk (2023). Blockchain Principles and Energy Consumption Concerns, Proceedings of the 27th International Conference on Information Technology (IT), Zabljak, Montenegro, 2023, pp. 1-5. DOI: 10.1109/IT57431.2023.10078571.

[33] N. Kapidani, S. Bauk, I. E. A. Davidson (2021). Developing Countries' Concerns Regarding Blockchain Adoption. Journal of Marine Science and Engineering, 9(12), 1326. DOI: https://doi.org/10.3390/jmse9121326.

[34] N. Kapidani, S. Bauk, I. E. A. Davidson (2021). Deploying Blockchain in Maritime: Developing Environments' Concerns. High Technology Letters, 27(9), pp. 942-951.

[35] Y. Zhou, Y. S. Soh, H. S. Loh, K. F. Yuen (2020). The key challenges and critical success factors of blockchain implementation: Policy implications for Singapore's maritime industry. Marine Policy, 122, 104265. DOI: https://doi.org/10.1016/j.marpol.2020.104265.

[36] M. Orcutt (2019 February 19). Once hailed as unhackable, blockchains are now getting hacked. In MIT Technology Review. Retrieved from: https://www.technologyreview.com/20-19/02/19/239592/once-hailed-as-unhackable-blockchains-are -now-getting-hacked/.

[37] M. Burgess M (2021). Artificial intelligence – How machine learning will shape the next decade. Penguin Random House, London, UK, p.165.

[38] U. Sakaran, R. Bougie (2018). Research Methods for Business, 7th ed.; Willey: New Jersey, USA.

[39] P. S. Poduval, V. R. Pramod, V.P. Jagathy Raj (2015). Interpretive Structural Modeling and its application in analyzing factors inhibiting implementation of Total Production Maintenance (TPM). International journal of Quality & Reliability Management, 32(3), 308-331. DOI: 10.1108/IJQRM-06-2013-0090.

[40] A. K. Digalwar, G. Giridhar (2015). Interpretive Structural Modeling Approach for Development of Electronic Vehicle Market in India. The 12th Global Conference on Sustainable Manufacturing, Procedia CIRP 26, pp. 40-45. DOI: https://doi.org/10.1016/j.procir.2014.07.125.

[41] S. Chandramowli, M. Transue, F. Felder (2011). Analysis of Barriers to Development in Landfill Communities Using Interpretive Structural Modeling. Habitat International, 35, pp. 246–253.

[42] A. Naim, Q. Ayman (2021). SmartISM: Implementation and Assessment of Interpretative Structural Modeling. Sustainability, 13, 8081. DOI: http://doi.org/10.3390/su13168801.

[43] J. P. Saxena, P. Vrat (1990). Impact of Indirect Relationships in Classification of Variables—A MICMAC Analysis for Energy Conservation. Systems Research, 7, pp. 245–253. DOI: https://doi.org/10.1002/sres.3850070404

[44] R. Dubey, S. Ali (2014). Identification of Flexible Manufacturing System Dimensions and Their Interrelationship Using Total Interpretive Structural Modelling and Fuzzy MICMAC. Analysis. Glob. J. Flex. Syst. Manag., 15, pp. 131–143. DOI: https://doi.org/10.1007/s40171-014-0058-9.

[45] M. Ahmad et al. (2019). Interpretative Structural Modeling and MICMAC Analysis for Identification and Benchmarking Significant Factors of Seismic Soil Liquefaction. Applied Sciences, 9, 233. DOI: 10.3390/app9020233.

[46] H. Bashir, U. Ojiako (2020). An integrated ISM-MICMAC approach for modelling and analyzing dependencies among engineering parameters in the early design phase. Journal of Engineering Design, 31(8-9), pp. 461-483. DOI: http://doi.org/10.-1080/09544828.2020.1817347

[47] G. Balci, E. Surucu-Balci (2021). Blockchain adoption in the maritime supply chain: Examining barriers and salient stakeholders in containerized international trade. Transportation Research Part E, 156, 102539, DOI: http://doi.org/10.1016/-j.tre.2021.102539

[48] R. K. Yin (2018). Case Study Research and Applications: Design and Methods, 6^{th} ed.; Thousand Oaks, CA: Sage.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 81–87

ISSN: 1697-4840, www.jmr.unican.es

The effectiveness of the smart sea ports operations within smart cities

Karim Mohamed Ali Aboul-Dahab[1,*]

ARTICLE INFO

Article history:
Received 17 May 2023;
in revised from 28 Jun 2023;
accepted 31 Aug 2023.

Keywords:
Smart Mobility Technologies, City Planning for Smart Mobility, logistics center, internet of things (IOT), Logistics 4.0.

ABSTRACT

Global population growth encourages the coordination between urban city planning and other stakeholders in order to maximize logistics utilization of Technologies 4.0, many researchers investigated the different factors affecting the implementation of smart cities, these factors includes technological and social factors that considerably affect the transformation toward a smart environment, for instance ,smart cities can't run properly without smart logistics solutions, the Implementation of advanced technologies solutions in the smart cities will facilitate the flow of goods and the transportation as well, in this respect, Smart logistics is a necessary condition to efficiently provide mobility to the transportation and flow of goods within smart cities, respectively, sustainable sea ports entails to integrate the business strategies and operations in way that meets the present and projected needs of the port and its stakeholders while safeguarding and protecting the marine environment, this paper aims to present the role of smart sea ports in the transformation of coastal cities in to smart cities.

1. Introduction.

The emergence of the smart city concept has brought a paradigm shift in urban mobility systems. Today, with technologies such as Internet of Things (IOT), Wireless Sensor Networks, Data Analytics, Big Data, etc., the transportation sector is seeing a new scope for significant changes and transformations. Today, the transport sector has become a complex system with services integrated into one platform governed by technology, In this regard, IoT technologies entails to speed up data collection and provision on rural transportation, making it possible for local authorities to provide exhaustive information of the current usage trends in a specific area, which could lead to a more effective action coordination between authorities at different levels. [23]

Accordingly sustainable urban mobility intent to meet the needs of society to move freely, gain extensive access to desired locations, communicate, negotiate and make relationships without sacrificing other values. [21], alternatively, the concept of smart logistics aims to increase the efficiency, safety, and eco-friendliness of the logistics environment.

In this respect, port connectivity entails to secure collaboration between ports and adjacent cities. Ports as a logistical centers facilitate freight and passenger transportation, hence Ports play an important role in international trade and have an impact on adjacent communities by lowering transportation costs for commodities and people.

According to (Uckelmann, 2008), Smart Logistics integrates existing logistic technologies, such as material handling systems, and enable these to react and act in a correspondingly smart manner [28].

2. Smart Logistics.

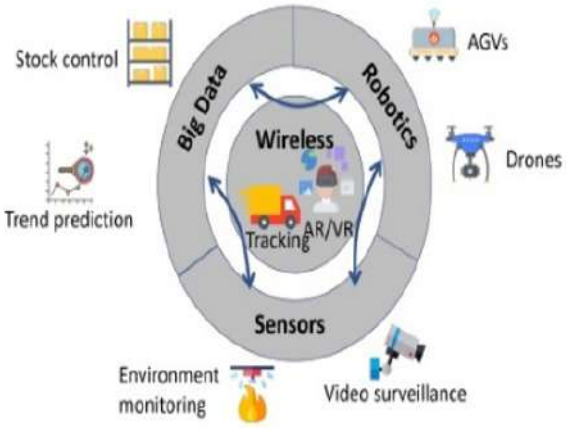
Smart logistics is a key solution to cope with the challenges in supply chain management, Smart Logistics can be defined as the combination of traffic management structuring and navigating traffic for optimal use of traffic systems and logistics management (organizing, planning, control and execution of the flow goods) by effective usage of data, Respectively, Logistics 4.0 can be defined as networking the whole supply chain through information technologies (IT), where high technologi-

[1]Arab Academy for Science, Technology and Maritime Transport (AASTMT), Egipt.

[*]Corresponding author: Karim Mohamed Ali Aboul-Dahab. E-mail Address: goldenntra@gmail.com.

cal sensors and advanced robotics are used in operations Logistics centers in the new industrial era[5].

Figure 1: Depicts the smart logistics supply chain process.



Source: Adopted from Khatib, Emil Jatib, and Raquel Barco (2021).

According to (Kauf, Sabina,2019), the biggest influence of smart logistics for realization smart city concept is visible in area of smart mobility which means huge web of connections, transport and communication with big speed of connecting all of the resources of the city, in this respect, an intelligent systems of transport (ITS) can be defined as a network that maximize the use of existing infrastructure through a range of technological means, such as traffic signals, travel planners, smart ticketing, and cooperative systems [2], accordingly the implementation of the (ITS) is expect to provide the smart cities residence the following benefits;

- Improvement of safety of traffic (decrease of car accidents by 40-80%).
- Decrease time of traveling and use of energy by 45-70%.
- Improvement of convenience of traveling and conditions of traffic of drivers that are traveling by collective transport and pedestrians.
- Reduction of costs of management of traffic supply train.
- Reduction of costs connected to maintenance and renewal of surface.
- Improvement of quality of natural environment (reduction of exhaust fumes by 30-50% increase of economic advantages [15].

3. The implementation of IOT in the logistics sector.

Internet of Things (IOT) includes all machines, devices and services connected via electricity grids and information systems, such as solar panels, weather stations, heating and air conditioning, washing machines, dishwashers' light bulbs, or electric vehicles, furthermore, it can also support the efficiency of public service delivery in a number of ways. For instance, by enabling street objects (street lamps, parking meters) to communicate, which allows a continuous monitoring of their performance and scheduling maintenance only when it is needed – or predict when there is danger of a breakdown, in this regard, the Netherlands adopted IOT technologies to better plan and manage shipping and reduce the ecological footprint of the port of Rotterdam [13].

3.1. Intelligent Transportation Systems (ITSs).

Intelligent Transportation Systems (ITSs) are advanced intermodal transport networks used for smart cities. As one of the key tenets of mobility solutions, ITSs are specialized systems for data collection, storage, and processing and provide expertise in the planning, execution, and assessment of the integrated initiatives and policies of smart mobility [9].

Given the increasing traffic volume, a modern port should ensure high cargo handling performance, reliability, and efficiency, as well as a reduction in vessel waiting time in the port and uninterrupted operation. This necessitates improvements in logistics organization as well as the application of new digital technology.

3.2. Internet of Vehicles (IOV).

Internet of Vehicles (IOV) is an open and integrated network system with high manageability, controllability, operationalization and credibility and is composed of multiple users, multiple vehicles, multiple things and multiple networks. Based on the cooperation between computation and communication [29], IOV is evolving from Vehicular ad hoc Networks (VANETs) to achieve the vision of 'from smartphone to smart car'. The sole aim of conventional VANETs is to enhance traffic safety and efficiency using real time communication among advanced wireless access technology enabled vehicles with or without the help of Road Side Units (RSUs) [18],the backbone of the system rests on a fast, reliable and high-bandwidth connection that is possible only with 5G's speed and performance [15].

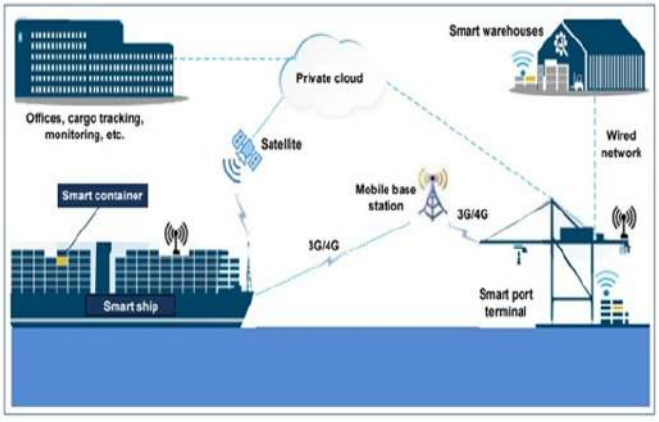
3.3. Block chain technology.

The Block chain technology (BC) acts as a database, whereby the data must be stored permanently and without contradiction along the supply chain (SC). In this way, a complete, cross company data and information flow along the entire SC can be ensured. [4], respectively, IBM and Maersk have announced in 2017 a collaboration agreement to implement Block chain technology in the supply chain, whereby it has been considered as one of the biggest steps to integrate Block chain with IOT in order to transform a global supply chain [22].

In the same essence, the "Internet of Ships (IoS) is the interconnecting of sensing objects like ships, crews, cargoes, onboard equipments, waterway environment, waterway facilities, shore based facilities and other navigation elements, which are embedded with a variety of sensor and heterogeneous network technologies to enable these objects to collect and exchange

data". IoS enables the monitoring of vessels and on-board equipment in real-time. Furthermore, ship owners can perform data analytics on historical and current data to enhance the vessel's efficiency and minimize fuel consumption [1].

Figure 2: Depicts the Internet of ships communication environment at sea.



Source: Adopted from Aslam, S., Michaelides, M. P., & Herodotou, H. (2020). Internet of ships: A survey on architectures, emerging applications, and challenges.

3.4. Radio Frequency Identification (RFID).

RFID is a type of auto ID technology that uses radio waves (as the name Radio Frequency Identification denotes) to identify, monitor and manage individual objects as they move between physical locations, With RFID systems, companies would have increased product visibility, reduce out-of-stock items, trim warehouse costs, eliminate stock errors, reduce theft and shrinkage and allow companies to regularly update their logistics and inventory databases [3]. Respectively (Cho, Gyu-Sung, 2018) proposed the implementation of Warehouse Management System (WMS) in the logistics centers which automatically trigger barcode or RFID information attached to the pallets required for warehouse automation and automates both goods receipt and warehousing in a way that interoperates with shuttle, stacker crane, or satellite.

In that context, (Cimini, et al , 2020) shed light on the utilization of drones to undertake the monitoring tasks required to overview the warehouses security and during picking or inventory auditing, moreover, the research reviewed the use of collaborative robots to assist in the process of pickn'-place, loadn'-unload, inspection, kitting and packing activities of parts and products.[24], in this respect ,Amazon started using robotics in 2012, and currently has 26 of its fulfillment centers worldwide using robotics and people together. [19],Similarly ,DHL smart warehouse deployed a team of autonomous mobile robots (AMRs) in their smart warehouse in the Netherlands, consequently ,the robots can move freely between pickers and packagers, which means people will spend less time on their feet moving around the warehouse and more time performing the more demanding task of picking [13].

Currently, simulation modelling of the port terminal is used at levels associated with ship movement, ship handling on the terminal quay, and container handling. This enables for better utilization of terminal resources and overall performance.

Reducing the time the vessel spends in port, among other things, decreases the environmental impact. Tagging is commonly used in Smart Warehouses, with low-cost identification devices such as RFID. Sensors and actuators, in conjunction with radar or cameras mounted on forklift trucks, can assure the proper operation of self-driving warehouse forklifts [14].

In this respect , (D'Amico, G.,et al , 2021) highlighted the role of the RFID in the port of Hamburg in monitoring the movement of containers, checking the expected delivery and which port processes and infrastructures must be used for correct routes management [8].

4. 5G Logistics.

Connectivity is a key feature of smart mobility, which, together with large data, enables consumers to send all travel data instantaneously while members of the local municipal administrations may perform strategic control simultaneously.

The evolving of fifth generation (5G) networks is becoming more readily available as a major driver of the growth of IOT applications ,Respectively (Liu, Mei.,2021) suggested that 5G technology can be widely used in logistics, mainly because of the close relationship between logistics and the Internet of Things. The massive access characteristics of 5G promote the application of the Internet of Things in the logistics industry and promote the intelligent development of logistics [21], consequently (Khatib, Emil Jatib, and Raquel Barco,2021) proposed a non-standalone (NSA) system mode of 5G centered around the needs of logistics, the research demonstrated that the possibility of outsourcing the communications management (while keeping confidentiality thanks to end-to-end encryption), the displace costs of ownership, communications infrastructure equipment and management, security patches, universal connectivity solution were among the main benefits of 5G implementation on the logistics industry [19].

According to (Chamarajnagar, Ravishankar and Ashwin Ashok, 2019), The 5G-IoT architecture should be able to satisfy the services requirements from following aspects:

- Scalability, cloudification/network function virtualization (NFV).
- Network virtualization capability.
- Sophisticated network management, includes mobility control, access control, and resource efficient network virtualization.
- Smart services provider, the architecture should be able to provide smart services based on big data analysis. [9]

from a different perspective the IOT in a 5G framework mainly comprises of five layered architecture; IOT Sensor Layer, Network Layer, Communication Layer, Architecture Layer, Application Layer which involves the operation of collecting data,

processing, analyzing and sharing the information between the devices and communication network [11].

In this respect, the Hamburg Port uses 5G-based networks to monitor vital infrastructure via enabling virtual reality, while the Seville Port exploits mobile network technology for monitoring goods and traffic in the port in real Time.[16] , accordingly , In May 2020, three Chinese enterprises (Dongfeng Motor Corporation, China Mobile Limited and China COSCO SHIPPING Corporation) jointly launched a project to implement a 5G-based smart port full-scene demonstration application at Yuanhai Terminal in Xiamen, East China's Fujian Province.

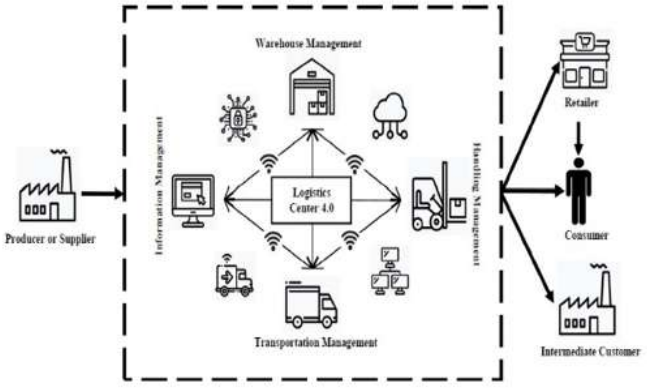
The solution gives a comprehensive way to operate unmanned container trucks, high precision positioning, and multi-sensor fusion based on Beidou Navigation System, plus 5G-based port machinery remote control transformation [7].

5. Smart Logistics Center.

Logistic Center can be defined as a hub of a specific area where all the activities relating to transport, logistics and goods distribution – both for national and international transit – are carried out, on a commercial basis, by various operators [14], The new technological developments of logistics through Industry 4.0 are expected to alter LCs' operations including handling, warehousing, distribution, and transportation, where smarter systems are needed.

In this regard (Yavas, Volkan, and Yesim Deniz Ozkan-Ozen,2020) examined the factors affecting the four main functions (Handling Management ,Information Management ,Transport Management and Warehouse management)of a logistic center 4.0 , the study found that digital information platforms and intelligent transportation systems , along with real time locating system are considered as the main factors affecting the smart logistic center operations ,accordingly (Kostrzewski,et al ,2021) suggested that adoption of modern cargo identification systems and modern warehousing technology will boost the logistic centers operations efficiency [17].

Figure 3: Shows the smart logistics center operations.



Source: Adopted from: Yavas, Volkan and Yesim Deniz Ozkan-Ozen, 2020.

From another perspective, an interregional logistic center entails to carry out integrated logistics (information, storage and transport) services to the inter-regional and international level in the organization of a full cycle of transportation management, respectively, (Gafurov, Ilshat, Michael Panasyuk, and Elena Pudovik,2014) suggested the town of Sviyazhsk to host the Network of inter-regional and international logistics centers (ILCs) in the Russian federation in order to perform the following functions;

- Support of process of planning, organization and implementation of rational delivery of foreign trade goods;
- Providing cargo owners and other parties concerned with information on transport and other operations involving transport of foreign goods to meet consumer demand of users;
- Technological connections with the international logistics system;
- Development of a single scheme of national transport infrastructure complex, etc. [20].

The smart logistics center optimize the performance of the following operations:

(i) Monitoring: governments can observe and record the status and flow of their supply chain;
(ii) Measuring: the supply chain performance can be measured without incurring in additional costs;
(iii) Controlling: governments and states can modify and reevaluate the implementation of their business operations if required;
(iv) Automating: warehousing operations can be initiated or ended even without human intervention;
(v) Optimizing: coordination among people, products, and means can be improved;
(vi) Learning: analytics can be provided that inform managers of Weaknesses and strengths in their supply chain Scientific and technological research article.

5.1. Smart Ports.

According to (ITU-T, recommendation Y.4209 (2020) smart port is expected to provide services that enable the enhancement of the user experience in the port, including passengers, visitors and port employees. A smart port may interoperate with the port area of influence, with one or more smart cities, with other smart elements (e.g., airport, railway stations) and with third parties (e.g., stakeholders, service providers). A smart element is regarded in this Recommendation as a logical or physical entity that is typically part of the smart city ecosystem (e.g., railway stations, airport) but not necessarily (i.e., the smart port is an independent smart element that might not be related to any city), and that interoperates with the city itself or with any of the rest of the smart elements [26].

The UNCTAD report in 1999 classified sea ports in to four generations, the first generation entails to stevedore cargo between land and sea-based means of transport. In this generation

the seaport operates in isolation from transport and the commercial function. The second generation ports, integrate with their surroundings via their transport, industrial, and commercial function. Within the port areas, industrial parks are created to receive imported raw materials delivered by sea , The third generation ports are characterized by higher activity than the previous generations, in connection with searching for cargoes by implementing the strategy of development which fosters the creation of integrated logistics centers and even logistics platforms supporting international trade, The fourth generation ones play a super-regional role creating a hub, where Port authorities are interconnected by a common administration (such as in the case of ports in Copenhagen and Malmo) or a common operator of the container terminal. respectively Kaliszewski, A. (2017) referred to the fifth generation of sea ports as having deep IT integration with various stakeholders, where, port operations enables an undisturbed exchange of cargo between the port and its hinterland, and ensure a high level of security, cost rationality, and generate progressively smaller external effects on the environment [20].

Respectively, (Chen, J., et al, 2019) suggested that the first four generations of ports paid far too little attention to port technology innovation and environmental protection, failed to achieve green and low-carbon development, and neglected issues such as climate change and environmental pollution. Global climate warming is one of the huge challenges facing mankind, and people in all walks of life must endeavor to save energy and reduce emissions. Port pollution greatly affects the climate environment. Most of the pollution comes from port production and transport ships. Approximately 70% of the world's marine emissions occur in the coastal area of the port, whereas 60–90% occurs during the berthing period [6]. In this respect, Piraeus Port Authority (PPA) and the Huawei Technologies SA have signed a mutual agreement in 2018 with the aim of modernizing the Piraeus ports main networks, Moreover to maintain high network services availability, and to increase the internet speed data rates from 20Gbps up to 80Gbps, which will make the port network infrastructure capable of supporting any future need as well as shielding against network threats [14].

Accordingly, port cities engaged in smart and sustainable logistics aim to involve institutions, citizens, start-ups, high tech companies, research centers, universities, freight forwarders, couriers, financial institutions, etc. in activities of planning, design, monitoring, analysis, evaluation and redefinition of logistics strategies that embrace the economic, social, environmental and technological spheres [8].

According to (Giménez, P., ,et al,2021)Typical logistic operations within a port can be enhanced due to interoperability, e.g. parking space availability, container status, availability of unloading/loading capabilities at the container terminals, ETAs (Estimated Time of Arrival), and remaining driving times [11].

As it's demonstrated in figure (3), smart port needs a smart port platform in order to provide the smart ports with smart services and interoperation capabilities, the smart port platform includes computer system or integration of computer systems that, under control of the port, uses information and communication technologies (ICTs) to access data sources and process

Figure 4: Shows the main components of the smart port ecosystem.

Source: Adopted from: ITU-T, recommendation Y.4209 (2020).

them to offer both port operation and services.

According to (Rodrigo González, A, et al, 2020) digitalization can play an important role covers the whole range of port activities. It allows for a substantial potential improvement in the following fields:

- Greater efficiency in operations (which leads to better economic returns);
- Worker safety;
- Active and dynamic communication with the social environment;
- Port management at an institutional level;
- Environmental and energy sustainability [23].

Furthermore, according to (Triska, Y.,et al , 2019) an automated container terminal can save at least 25% more energy and reduce 15% more carbon emissions than the traditional terminal as a result of using power-driven vehicles [27].

5.2. The smart ports effectiveness in the coastal cities .

Sea Ports serve as logistical hubs which facilitates freight and people transportation and hence interconnection between sea ports and cities is more important than ever before. Subsequently, Ports play an important role in international trade and have an impact on adjacent communities by lowering transportation costs for commodities and people.

Seaports has a significant economic and environmental effect in coastal cities more than other cities. The city-port interface zone connects the city to its port directly. The new economic development programs considered the sustainable operations of the sea ports operations as one of the main objectives,

especially with the increasing volume of freight traffic and the growing demand for rapid, efficient, reliable, and environmentally friendly logistics solutions, in this respect, the united nations Sustainable Development Goals (SDG 9) aims to build resilient infrastructure, promote sustainable industrialization and foster innovation.

In this respect, "port city" can be defined as a city with a maritime hub, where the port acts as a junction point between land and sea transport networks. According to this concept, global trade starts from the hinterland, whereas ports are points of arrival and departure. Ports are strengthening the competitiveness of a city and increase the economic prosperity of a region [12].

According to (Yulai Wan , Anming Zhang & Andrew C.L. Yuen ,2013) a 1% increase in road congestion is associated with 0.90–2.48% reduction in the container throughput of the seaport affiliated with that urban area, while implying an increase in the throughput of its rival port by 0.62–1.69% [30].

Efficiency is one of the characteristics of successful logistics. It is critical to deliver items from point A to point B as quickly and smoothly as possible. Fast clearance, as well as an invisible registration process and easy processing operations, such as with customs, are essential. Indeed, new digital platforms have created an electronic "parallel world" that supports genuine commodities delivery, making it speedier and more transparent.

The best collaboration can be achieved by developing an interconnected integrated system of good transport infrastructure for all modes of transportation and cargo owners, as well as a unified information environment of technological interaction between various modes of transportation and transport process participants for a modern distribution network, ensuring the volume and quality of transport services.

In this context, Block chain technology provides security, transparency and decentralization of processes.

Respectively, Logistics centers is a vital component of global logistics networks that provides efficient terminal handling and cost-effective logistics solutions for a variety of transport flows. Logistics centers may have diverse business processes in marketplaces, trade, and industry, or logistics service provider systems. These logistics parts are often formed on a market basis, but cities may also be active in establishing logistics areas and may even initiate campaigns to do so.

Accordingly, Eckhardt, J., & Rantala, J. (2012) investigated the effectiveness of smart logistics center that relies on RFID technology in enhancing the efficiency of logistics operations and also in developing new service models for their customers. Moreover, the smart logistics center promote the tracking and tracing of material flows including effective handling processes ,along with maintaining cost-efficiency throughout the supply chain.

Conclusions

Logistics centers play a key role in ecommerce because they determine where you will store your inventory, how soon you can deliver customer orders, and the different types of shipping options you can offer your customers.

IOT technologies, especially block chain technology and RFID with sensors, can guarantee the safety and quality of goods, particularly perishable products, by collecting, monitoring, and tracking ambient environmental conditions during delivery.

5G can be widely used in logistics, mainly because of the close relationship between logistics and the Internet of Things. The massive access characteristics of 5G promote the application of the Internet of Things in the logistics industry and promote the intelligent development of logistics. The new generation of logistics has a complex structure system.

5G network adoption will have a significant impact on high-end IoT applications such as robots and automation, virtual and augmented reality, and artificial intelligence.

Logistics efficiency is improving as the automation of logistics centers and logistics facilities around the world is progressing. In particular, advanced systems introduced in logistics centers have replaced manpower while carrying out tasks that are difficult for people to do. logistics center based on IoT and ICT, utilize and analyze smart technology such as Big Data, and optimize the storage, transportation, unloading, packaging and delivery of products based on the analyzed knowledge.

Smart ports are intended to operate and manage modern ports by utilizing advanced intelligent technology and procedures. To realize smart and green port operation, the construction and sustainable growth of a smart port should be built on the concepts of cooperative cooperation, technological innovation, environmental protection, energy conservation, and full use of information technology.

References.

[1] Aslam, S., Michaelides, M. P., & Herodotou, H. (2020). Internet of ships: A survey on architectures, emerging applications, and challenges. IEEE Internet of Things Journal, 7(10), 9714–9727. https://doi.org/10.1109/jiot.2020.2993411.

[2] Bıyık, Can, Ahmad Abareshi, Alexander Paz, Rosa Arce Ruiz, Rosaria Battarra, Christopher D. Rogers, and Carmen Lizarraga. "Smart Mobility Adoption: A Review of Literature." Journal of Open Innovation: Technology, Market, and Complexity 7, no. 2 (2021): 146. https://doi.org/10.3390/joitmc7020146.

[3] B, Kamaladevi. "RFID – The Best Technology in Supply Chain Management ". International Journal of Innovation, Management and Technology 1, no. 2 (2010). ISSN: 2010-0248.

[4] Berneis, Moritz, Devis Bartsch, and Herwig Winkler. "Applications of Blockchain Technology in Logistics and Supply Chain Management—Insights from a Systematic Literature Review." Logistics 5, no. 3 (2021): 43. https://doi.org/10.3390/logistics5030043.

[5] Cimini, Chiara, Alexandra Lagorio, David Romero, Sergio Cavalieri, and Johan Stahre. "Smart Logistics and the Logistics Operator 4.0." IFAC-PapersOnLine 53, no. 2 (2020): 10615–20. https://doi.org/10.1016/j.ifacol.2020.12.2818.

[6] Chen, J., Huang, T., Xie, X., Lee, P., & Hua, C. (2019). Constructing governance framework of a green and smart port. Journal of Marine Science and Engineering, 7(4), 83. https://doi-.org/10.3390/jmse7040083 challenges. IEEE Internet of Things Journal, 7(10), 9714–9727. https://doi.org/10.1109/jiot.2020.2-993411.

[7] China's first 'smart port 2.0' starts operation. (n.d.). Retrieved May 7, 2023, from http://en.sasac.gov.cn/2022/01/05/c_-11020.html.

[8] D'Amico, G., Szopik-Depczyńska, K., Dembińska, I., & Ioppolo, G. (2021). Smart and Sustainable Logistics of Port Cities: A Framework for comprehending enabling factors, domains and goals. Sustainable Cities and Society, 69, 102801. https://doi.org/10.1016/j.scs.2021.102801 .

[9] Chamarajnagar, Ravishankar, and Ashwin Ashok. "5G Cloud, Mobile, and Edge Computing for the Internet of Things". 5G-Enabled Internet of Things, 2019, 3–27. https://doi.org/10.1201-/9780429199820-1.

[10]Eckhardt, J., & Rantala, J. (2012). The role of Intelligent Logistics Centres in a multimodal and cost-effective transport system. Procedia - Social and Behavioral Sciences, 48, 612–621. https://doi.org/10.1016/j.sbspro.2012.06.1039.

[11] Giménez, P., Llop, M., Meseguer, J., Martin, F., & Broseta, A. (2021). INTER-logp: Inter-iot for smart port transportation. Internet of Things, 257–277. https://doi.org/10.1007/978-3-030-82446-4_9.

[12] Gurzhiy, A., Kalyazina, S., Maydanova, S., & Marchenko, R. M. (n.d.). Port and city integration: Transportation aspect Transportation Research Procedia 54 (2021) 890–899.

[13] How smart logistics is helping to fuel change at DHL. DHL Spotlight. (n.d.). Retrieved February 24, 2022, from https://www.dhl.com/global-en/spotlight/smart-logistics.html.

[14] Huawei to modernize network infrastructure in port of Piraeus. SAFETY4SEA. (2018, January 26). Retrieved May 7, 2023, from https://safety4sea.com/huawei-to-modernize-network-infrastructure-in-port-of-piraeus/.

[15] Introducing 5G and how it impacts logistics: Discover DHL. Introducing 5G and How It Impacts Logistics | Discover DHL. (n.d.). Retrieved February 24, 2022, from https://www.dhl-.com/discover/en-global/business/productivity/5g-and-logistics.

[16] Ilin, I., Jahn, C., Weigell, J., & Kalyazina, S. (2019). Digital technology implementation for Smart City and smart port cooperation. *Proceedings of the International Conference on Digital Technologies in Logistics and Infrastructure (ICDTLI 2019)*. https://doi.org/10.2991/icdtli-19.2019.87.

[17] Kostrzewski, Mariusz, Ludmiła Filina-Dawidowicz, and Szymon Walusiak. "Modern Technologies Development in Logistics Centers: The Case Study of Poland." Transportation Research Procedia 55 (2021): 268–75. https://doi.org/10.1016/j.tr-pro.2021.06.031.

[18] Kaiwartya, Omprakash, Abdul Hanan Abdullah, Yue Cao, Ayman Altameem, Mukesh Prasad, Chin-Teng Lin, and Xiulei Liu. "Internet of Vehicles: Motivation, Layered Architecture, Network Model, Challenges, and Future Aspects." IEEE Access 4 (2016): 5356–73. https://doi.org/10.1109/access.2016.2-603219.

[19] Khatib, Emil Jatib, and Raquel Barco. "Optimization of 5G Networks for Smart Logistics." Energies 14, no. 6 (2021): 1758. https://doi.org/10.3390/en14061758.

[20] Kaliszewski, A. (2017). Fifth and Sixth Generation Ports (5GP, 6GP) - EVOLUTION of the economic and social role of ports. Studies and Materials of the Institute of Maritime Transport and Trade, (14), 93–123. https://doi.org/10.26881/sim.20-17.4.06.

[21] Liu, Mei. "Research on the Development of Intelligent Logistics Based on 5G Technology." 2021 2nd International Conference on Urban Engineering and Management Science (ICUEMS), 2021. https://doi.org/10.1109/icuems52408.2021.0-0029.

[22] Paiva, Sara, Mohd Ahad, Gautami Tripathi, Noushaba Feroz, and Gabriella Casalino. "Enabling Technologies for Urban Smart Mobility: Recent Trends, Opportunities and Challenges." Sensors 21, no. 6 (2021): 2143. https://doi.org/10.3390/s21062143.

[23] Porru, Simone, Francesco Edoardo Misso, Filippo Eros Pani, and Cino Repetto. "Smart Mobility and Public Transport: Opportunities and Challenges in Rural and Urban Areas." Journal of Traffic and Transportation Engineering (English Edition) 7, no. 1 (2020): 88–97. https://doi.org/10.1016/j.jtte.2019.10.0-02.

[24] Rožman, Nejc, Rok Vrabič, Marko Corn, Tomaž Požrl, and Janez Diaci. "Distributed Logistics Platform Based on Blockchain and IOT." Procedia CIRP 81 (2019): 826–31. https://doi.-org/10.1016/j.procir.2019.03.207.

[25]Rodrigo González, A., González-Cancelas, N., Molina Serrano, B., & Orive, A. (2020). Preparation of a smart port indicator and calculation of a ranking for the Spanish port system. Logistics, 4(2), 9. https://doi.org/10.3390/logistics4020009.

[26] TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU, ITU-T. (2020). (issue brief). Requirements for interoperation of the smart port with the smart city (Vol. 1, pp. 1–12). Geneva: International Telecommunication Union (ITU).

[27] Triska, Y., Albuquerque, J. V., Valente, A. M., Silva, L. D., Martinez Moya, J., Constante, J. M., & Frazzon, E. M. (2019). Smart Port-Hinterland Integration: Conceptual proposal and simulation-based analysis in Brazilian ports. International Journal of Integrated Supply Management, 12(1), 1. https://doi.org/10.1504/ijism.2019.10024097

[28] Uckelmann, Dieter. "A Definition Approach to Smart Logistics." Next Generation Teletraffic and Wired/Wireless Advanced Networking, 2008, 273–84. https://doi.org/10.1007/978-3-540-85500-2_28.

[29] Yang, Fangchun, Shangguang Wang, Jinglin Li, Zhihan Liu, and Qibo Sun. "An Overview of the Internet of Vehicles." China Communications 11, no. 10 (2014): 1–15. https://doi.org/-10.1109/cc.2014.6969789.

[30] Yulai Wan , Anming Zhang & Andrew C.L. Yuen (2013) Urban road congestion, capacity expansion and port competition: empirical analysis of US container ports, Maritime Policy & Management: The flagship journal of international shipping and port research, 40:5, 417-438, DOI: 10.1080/03088839.2013-.797615.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 88–93

ISSN: 1697-4840, www.jmr.unican.es

Conceptual Design and Economic Analysis of a floating stadium for indoor games in the capital city of Bangladesh

Mrinal Kanti Roy[1,*], Md Samiun Nur Islam[1], Minhazul Islam[1], Md. Mashiur Rahaman[1], N. M. Golam Zakaria[1]

ARTICLE INFO

Article history:
Received 21 May 2023;
in revised from 28 Jun 2023;
accepted 01 Sep 2023.

Keywords:
Dhaka city, playground, conceptual design, floating stadium, economic analysis, viable solution.

ABSTRACT

The overpopulated city of Dhaka faces a severe shortage of open fields and playgrounds with a deficit of 152.80 acres. To address this problem, an alternative solution in the form of an Indoor Floating Stadium has been conceptualized. The stadium will be built on available calm water such as Hatirjheel, Dhanmondi Lake, Purbachal Ecopark lake, Nikunja Lake, Ramna Lake, Diabari Lake, and Chandrima Udyan, providing an open space for children and adults alike. It is expected to serve as a versatile venue for a variety of sports events and practice sessions for neighborhood or school-based sports teams. The stadium has the potential to inspire and educate the younger generation while connecting people from diverse backgrounds and ethnicities through the power of sports. The economic viability of the indoor stadium has been also analyzed, and it has been concluded that it is a viable solution for the city.

1. Introduction.

Youths are the foundational stones and the future of a country. Young generations are anticipated to be lively, with vibrant looks. This generation will be the country's and the world's future leaders. Dhaka has a very large population of around 22.5 million people. Almost half of these people are young, with around 9-10 million of them being youth. Young people used to wrestle as a form of entertainment in the past. This eventually became a popular social activity in which people would assemble in specific unoccupied spaces or sports grounds and engage in fun physical activities. This is a significant cultural trend that provides numerous benefits to people's physical, mental, and social well-being. Furthermore, young people are encouraged to be creative and think outside the box.

However, in recent years young people in Dhaka have faced a variety of physical, mental, and social issues due to a lack of playgrounds and physical activities. This has resulted in a decrease in their overall well-being, making it difficult for them to perform to their full potential. To cope with their depression and a lack of outlets for physical activity, many of them turn to drugs and illegal activities. (Whitebread, 2017). Most first-world countries like Japan, United States, United Kingdom, Canada, and Australia have an adequate amount of green space per person and have enough parks and playgrounds for children. Unfortunately, Bangladesh, India, and Pakistan do not have enough playgrounds for their children and security concerns make it difficult for children to visit the few that do exist (S.P. Dewi,2012). The Dhaka Metropolitan Development Plan (DMDP) reported that Dhaka City had 0.5 square meters of green space per capital in 1995. Now, Dhaka has only 0.052 square meters of green space per person, which is a concern for the population's physical and mental well-being, particularly for the youth, who have few options for outdoor play (WBB Trust,2015).

In another context, Dhaka has several notable lakes in strategic locations which are near residential and commercial areas, schools, and universities. The beneficial wetlands of Dhaka City have approximately 30-35 khals or natural drainage, totalling nearly 437 km^2 and including four major rivers: the Buriganga River, the Turag River, the Balu River, and the Tongi River (Marju Ben Sayed,2017).

Under this Circumstances, this study proposes an alterna-

[1]Department of Naval Architecture & Marine Engineering, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh.

[*]Corresponding author: Mrinal Kanti Roy. E-mail Address: mkrhellol99@gmail.com.

tive solution to Dhaka's playground shortage. The proposal is to construct a Floating Indoor Stadium on available calm water such as Hatirjheel, Dhanmondi Lake, Purbachal Ecopark Lake, Nikunja Lake, Ramna Lake, Diabari Lake, Crescent Lake, and Chandrima Udyan rather than on land. This stadium can be used for various sporting events and team practices, as well as a place for children and adults to play and spend quality time. A floating stadium provides numerous benefits to athletes, youth, and the surrounding community.

2. Methodology.

Data were gathered in massive quantities by using a variety of methods, such as literature reviews, analyses of possible customers, and the selection of the most convenient places. Youths who are enrolled in school, college, or university are the target audience for data collecting. Additionally, different sports people are also asked to contribute to the survey. Surveys conducted through google forms and are regarded as primary data. Secondary information gathered from newspapers, journal and article reviews, and various literature reviews.

Primary data was analyzed and presented thorough charts, tables, diagrams, and other graphical methods. The optimum dimension was chosen after considering client demand and space availability in various lakes. The dimensions were chosen to accommodate other facilities as well as serving as a multipurpose indoor stadium. Additionally, design and construction should be done following client demand as figured out by surveys and international maritime standards.

Economic analysis of the project should afterwards be assessed after calculating the construction cost, operational cost, and other costs, as well as the revenue model. To calculate breakeven point the following formula is used.

$$\text{NPV} = 0$$

Where,

$$NPV = A \times \left(\frac{(1+i)^n - 1}{i \times (1+i)^n} \right) - P_0$$

A = Net income/year.
i = Discount rate.
P_0 = Initial Cost.

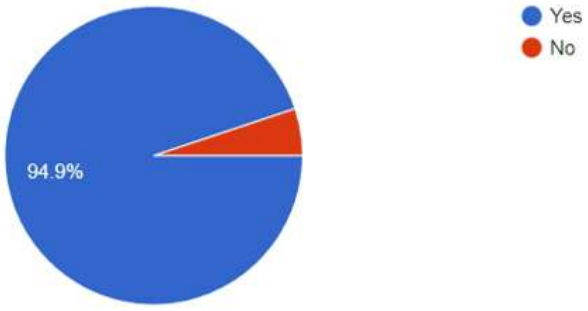
3. Result and Discussion.

This section focuses on the survey results obtained from the main stakeholders and customers. These results were used to develop drawings and conduct a cost analysis.

3.1. Survey Results.

People are asked questions to determine whether the market is ready to embrace the unique idea of a floating indoor stadium in the city of Dhaka. Most of the participating age group, which ranges from 21 to 25, has expressed interest in this initiative. The highest proportion comes from students and non-government employees. Almost people from all areas of Dhaka have participated in this survey and expressed interest, and 95% of people would be pleased to have this alternate solution to the playground crisis depicted in Figure 1.

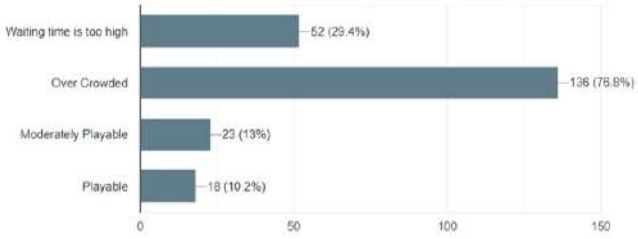
Figure 1: Interested in sports of the respondents.



Source: Authors.

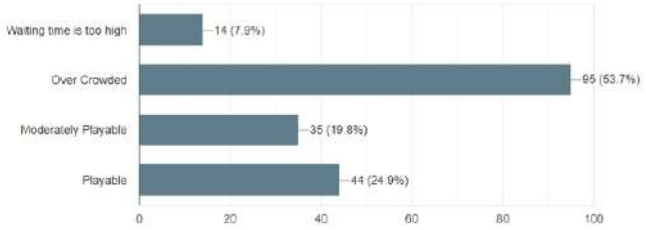
When stakeholders were questioned about the presence of playgrounds in the area, 40% of them said that there are no playgrounds at all. Respondents from the remaining 60% of the sample claimed that there was not much space for playing available. The following charts are a summary of the available playgrounds' condition.

Figure 2: Playground situation in holidays.



Source: Authors.

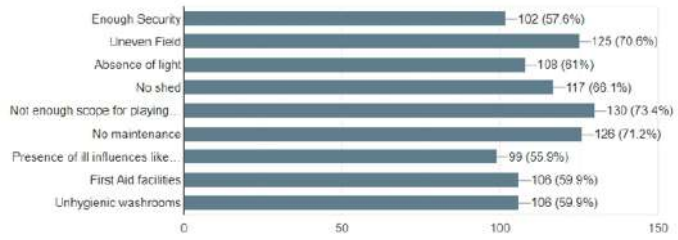
Figure 3: Playground situation in normal working days.



Source: Authors.

Figure 4 shows that a substantial number of respondents were unsatisfied with the current traditional playgrounds owing to a range of issues, including a lack of security, uneven field conditions, a lack of lighting, poor maintenance, a lack of first aid facilities, and unhygienic restrooms. In fact, more than half of the people surveyed expressed dissatisfaction with the playground's present state.

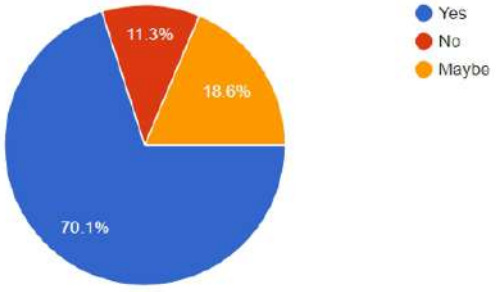
Figure 4: Scenario of visit to conventional existing playgrounds.



Source: Authors.

The people are then questioned on the acceptance of new ideas like a floating indoor stadium that would resolve all the playground-related issues**.** Figure 5 shows that almost 70% of respondents expressed interest in the floating indoor stadium.

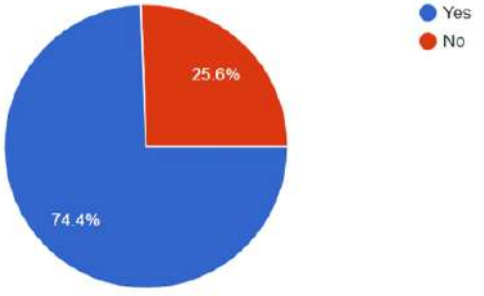
Figure 5: Opinion of the respondents about the floating stadium.



Source: Authors.

The willingness to pay is depicted in Figures. 6 and 7, and the preferred range is $5 to $20 per month. According to Figure 7, 57.1% of respondents are willing to pay between $5 and $10 to use the facilities.

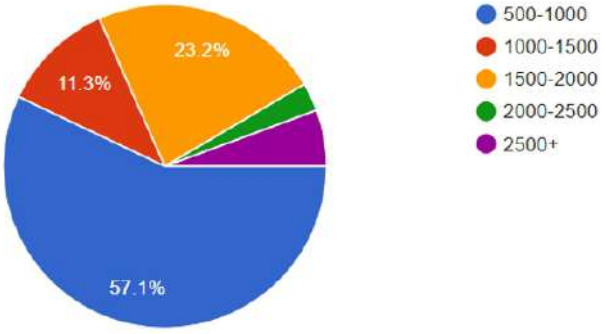
Figure 6: Willingness to pay.



Source: Authors.

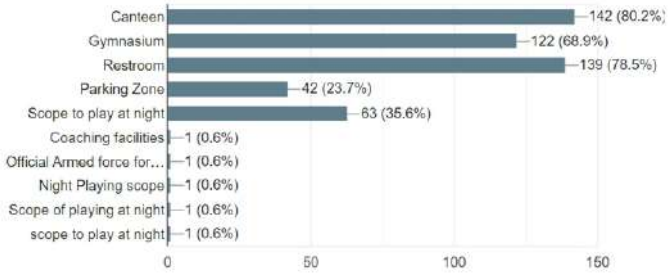
*Conversion Rate: 1 USD = 100 BDT.

Figure 7: Range of monthly payment (BDT).



Source: Authors.

Figure 8: Additional facilities requirements.



Source: Authors.

3.2. Selection of Location.

The current study took Tran's (My Tran, 2021) recommendations for consideration when deciding on a suitable location for the floating indoor stadium in Dhaka. Hatirjheel Lake, Gulshan Lake, Dhanmondi Lake, and Diabari in Uttara were identified. These locations were chosen because lakes are easily accessible, close to residential areas, and have good transportation options. Furthermore, the floating stadiums will not impede water transport in the lakes, and proper waste management can be implemented to minimize any negative environmental impact.

Figure 9: Location of Hatirjheel Lake.

Source: Authors.

Figure 10: Location of Gulshan Lake.

Source: Authors.

Figure 11: Location of Dhanmondi.

Source: Authors.

Figure 12: Location of Diabari Lake.

Source: Authors.

4. Design and Development.

The findings of the survey show that the targeted consumers are interested in a variety of sports and other amenities including gyms, medical centres, rest rooms, and restaurants. The actual construction of the indoor stadium that is well-equipped with the necessary amenities to satisfy the clients' requests represents the project's next big obstacle. In order to ensure safety, the floating stadium must also adhere to the International Maritime Organization's (IMO) stability criteria for stability and the environmental standards set by international classification societies. A preliminary General Arrangement (GA) Plan for the indoor stadium has been created with all of these considerations in mind. A draft General Arrangement (GA) Plan for the ship has been developed. Elevation, side view (gallery) and plan views of different deck have shown in Figure 12. 3D view of the floating indoor stadium has been also shown in Figure 13. The indoor stadiums' principal particulars are displayed in Table 1.

Table 1: Principal particulars of the Floating Indoor Stadium.

Item	Symbol	Value	Unit
Length Overall	L_{OA}	60.00	[meter]
Length Between Perpendiculars	L_{BP}	60.00	[meter]
Breadth Moulded	B_{MLD}	40.00	[meter]
Depth Moulded	D_{MLD}	2.50	[meter]
Draft Design	T	2.20	[meter]
Block Co-efficient	C_B	0.94	--

Source: Authors.

Table 2: Space available for different sports and activities.

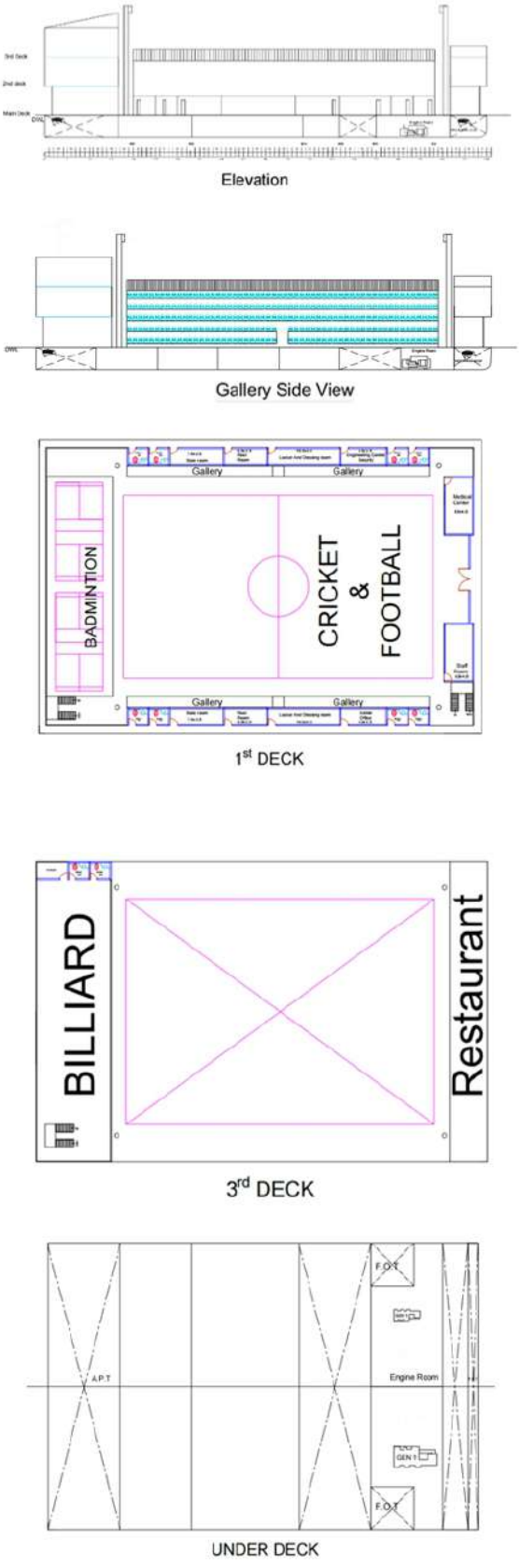
Sports/Activities	Length (Max) (m)	Width (Max) (m)
Football	42	25
Cricket	42	25
Billiard	32.5	10
Badminton	30	9
Kids Zone	35	5
Gymnasium	32.5	10

Source: Authors.

5. Economic Analysis.

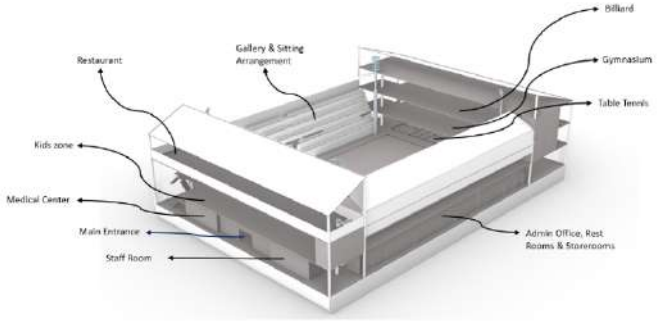
To determine the annual income, it is assumed that the entire floating indoor stadium is open for business 25 days out of every month, and that the capacity is utilized at 70% of its maximum level. The yearly cashflow is determined by taking the annual income as inflows and deducting the outflows, which consist of monthly wages, the bare minimum of operating expenses, and power bills. The summary of break-even calculation is shown in Table 3. It will take at least 6.83 years, assuming an 8% discount rate, to completely repay the initial construction cost. A detailed initial cost, revenue and expenses are given in appendix.

Figure 13: Preliminary General Arrangement Plan of the stadium.



Source: Authors.

Figure 14: 3D view of the Floating Indoor Stadium.



Source: Authors.

Table 3: Break-even point calculation.

Items	Amount
Initial construction cost	$1,425,927
Monthly operational cost	$5,780
Monthly revenue (70% utilization rate)	$29,020
Net income per year	$278,880
Breakeven point (8% discount rate)	6.83 Years

Source: Authors.

Conclusions.

For Bangladesh's capital city, the indoor floating stadium idea is unique and innovative. It will address real-world issues like the playground shortage in Dhaka and may offer a better setting for several athletic events and recreational amenities for residents of the capital city than the one now available. In addition, a comparable price with other indoor stadiums will give it a competitive advantage. Furthermore, it is clear from the economic study that the venture would reach full profitability after 6.83 years of operation if the entire business model and other problematic concerns are well managed. However, there are certain limitations on this study as well. The lack of reliable information about lakes, particularly the chosen places' depth and water quality are some important causes of limitations and if more people participated in the survey, then the findings would be more accurate.

Recommendations.

To get a clear idea of the practicability of this project a pilot project should be run. A thorough economic analysis should be conducted after obtaining the data from the pilot project.

References.

Dhaka Tribune. "Fitness centres growing into businesses." *August 26th, 2019.*

Dave Jensen Hanne Liu Claire Solis Lynneth Hopkins Emily Hirsh-Pasek Kathy Zosh Jennifer Whitebread, David Neale. "The

role of play in children's development: a review of the evidence."*2017*

Marju Ben Sayed and Shigeko Haruyama. "Flood risk measuring under the flood protection embankment construction in Dhaka metropolitan zone." *Journal of Geo-sciences and Geomagnetic, 5:46–58, 2017.*

My Tran. "Future floating stadiums case study: Honolulu hawaii." *Doctoral Thesis, The University of Hawaii.*

S. P. Dewi. "How does the playground role in realizing children-friendly-city?" *Procedia Soc Behav Sci, 38:224–233, 2012.*

Work for a Better Bangladesh (WBB Trust). "Parks and playgrounds in Dhaka: taking stock and moving forward a report on the characteristics of parks and playgrounds in Dhaka as well as recommendations for their improvement." *Doctoral Thesis, The University of Hawaii, 2015.*

Appendix.

Table 4: Calculation of total power required.

Type of Room	No of Room	Power Needed/ROOM	Total
Washroom	14	762	10668 W
Restroom	4	230	920 W
Admin Office Room	1	5505	5505 W
Storeroom	2	230	460 W
Security ROOM	1	380	380 W
Locker and Security Room	2	455	910 W
Staff Room	1	380	380 W
Medical Center	1	5655	5655 W
Badminton Court	1	1260	1260 W
Cricket/Football Court	1	12240	12240 W
BILLIARD	1	11970	11970 W
Gymnasium (Dhaka Tribune,2019)	1	21970	21970 W
Kids Zone	1	11970	11970 W
Restaurant	1	6180	6180 W
Gallery	2	710	1420 W
Outside Light	1	600	600 W
Machinery Room	1	220	220 W
Pump	2	1500	3000 W
		Total	**96 KW**

Source: Authors.

To meet up the electrical power, it uses two Ricardo Canopy Diesel Generators, each with a 50 KW output, to provide the required power. The selected generators are in-built foreign canopy Ricardo Series units, with a rated prime power of 50kVA / 40kW.

Table 5: Initial Construction Cost calculation.

Item	Qty	Unit Price	Total Price
Hull Construction Materials			
Steel Cost	903	$950	$858,203
Piping and Valve (5%)			$34,328
Paint Cost			$68,656
Power System Cost			
Generator	2	$4,700	$9,400
Switch + Switch Board +Socket + Light + FAN			$9,790
Cables			$500
Anchoring			
Anchor	4	$250	$1,000
Winch+ Mooring Ropes	4	$500	$2,000
Navigational Light (For Night)	2	$100	$200
Pumps			
General Service Pump	1	$240	$240
Sanitary Pump	1	$80	$80
Door and Window			
Door	32	$100	$3,200
Window	18	$300	$5,400
Transparent Thai Glass	3	$20,000	$60,000
Fire Extinguisher	20	$50	$1,000
Gymnasium Equipment			$75,000
Billiard Coat			$2,000
Kids Zone's Equipment			$2,000
Cricket/Football Carpet	1	$2000	$2,000
Badminton Carpet	1	$2000	$500
Accommodation			
Spectators Chair	100	$25	$2500
Toilet Fittings	14	$300	$4,200
Officer/Staffs Room			$1,000
HULL FABRICATION & YARD COST + Electric COST			$325,640
Block Transportation			$30,000
Total Initial Cost (USD)			$1,425,928

Source: Authors.

Table 6: Estimation of Revenue.

Annual Income	
Gymnasium	
No. Of Accommodation in 1 shift	60
No of Shift	5
Fees per month per person	$20
Total Income	$6,000
Badminton (2 Coat)	
No. Of Accommodation in 1 shift	8
No of Shift (1 hours)	10
Fees per person per shift	$2
Total Income per month (25 Days)	$4,000
Billiard (Coat 10)	
No. Of Accommodation in 1 shift	20
No of Shift (1 hours)	10
Fees per person per shift	$1.5
Total Income per month (25 Days)	$7,500
Kids Zone	
No. Of Accommodation in 1 shift	30
No of Shift (1 hours)	10
Fees per person per shift	$2
Total Income per month (25 Days)	$15,000
Football/ Cricket	
No of Shift (1.5 hours)	8
Fees per shift (as group)	$40
Total Income per month (25 Days)	$8,000
Sponsorship and advertising	
Average monthly earnings from sponsorship	$208
Cafeteria	
Monthly rent	$750
Total Income per month (25 Days)	$750
Overall Monthly Income	$41,458
Overall Yearly	$495,000
at 70% Capacity Utilization Rate	
Overall Monthly Income	$29,020
Overall Yearly Income (USD)	**$3,465,000**

Source: Authors.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 95–103

ISSN: 1697-4840, www.jmr.unican.es

A System Dynamics Model for the Sustainability of Naval Capabilities Toward Indonesia Maritime Security

Richard Martin[1,*], A. S. Leksono[1], Setyo Widagdo[1], Harsuko Riniwati[1]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 28 Jun 2023;
accepted 01 Sep 2023.

Keywords:
Naval Capabilities; Maritime Security; Indonesian Sea; System Dynamics Modelling.

ABSTRACT

Sustainability in the development of naval capabilities plays a crucial role to ensure national maritime security in future wars. This study seeks to provide an analysis of the sustainability framework for the enhancement of naval capabilities in the context of national maritime security. This study uses descriptive statistics, supported by the system dynamics (SD) model. Eight personnel, including academicians and practitioners, participated in the research, which was conducted between January 2022 and February 2023. Based on the study findings, it is projected that the value of naval capabilities will range from 3.77 to 3.78 between 2022 and 2027, indicating a highly capable status (level 4). However, there will be a slight decline in naval capabilities from 2022 to 2024, and naval capabilities will dynamically experience a slight decline. Subsequently, between 2024 and 2027, the naval capability is predicted to slowly increase, remaining within the range of 3.78 (highly capable). The development and establishment of naval capabilities are influenced by various factors, including dynamic and uncertain external and internal threats. Nonetheless, through the strengthening of capabilities, the addition of main equipment and weapon systems, and strategic operational patterns, there will be a gradual enhancement of defense capabilities. This, in turn, will facilitate the promotion and preservation of territorial claims and national interests, ultimately upholding national maritime security..

1. Introduction.

Indonesia is an archipelagic country located in Southeast Asia and Oceania. It occupies a strategic position between Asia and Australia, with the Pacific Ocean and the Indian Ocean surrounding its shores. Covering a vast land area of 1.9 million square kilometers, Indonesia ranks as the 14th largest country in the world in terms of landmass (Teniwut et al., 2019). One notable feature of Indonesia is its extensive coastline, stretching over 54,000 kilometers. Additionally, the country boasts an exclusive economic zone (EEZ) spanning approximately 6.1 million square kilometers. Its geographical location has made it a vital sea lane connecting the Pacific Ocean and the Indian Ocean. With around 40% of global maritime traffic passing through Indonesian waters, it serves as a vital pathway for international trade and commerce (Rochwulaningsih et al., 2019). The Indonesian Sea is the world's largest sea and plays an important role in international trade, national defense, and natural resource management (Kipgen, 2021).

This vast maritime territory is crucial for Indonesia's economic growth and national security. However, Indonesia faces significant challenges in ensuring its maritime security (Rismana et al., 2021). One of the primary challenges is illegal, unreported, and unregulated (IUU) fishing. Additionally, piracy and armed robbery at sea present a formidable challenge. The waters around Indonesia are among the most dangerous in the world in terms of piracy and armed robbery. Moreover, Indonesia must confront non-traditional security threats, including the degradation of marine environments and the impact of climate change. These threats have the potential to negatively affect the country's maritime resources and ecosystems. Furthermore,

[1]Brawijaya University, Veteran, Ketawanggede, Malang, East Java, Indonesia 65145.
[*]Corresponding author: Richard Martin. E-mail Address: ricardmartin0205@gmail.com.

terrorism also poses a threat to Indonesia's maritime security (Maulana, 2022).

Indonesia has taken steps to improve its counterterrorism capabilities by implementing various measures, including strengthening its coast guard and strengthening intelligence sharing with international partners. In response, Indonesia has stepped up its maritime security efforts by deploying more naval assets, conducting joint patrols with neighboring countries, and enhancing information sharing (Gartzke & Lindsay, 2020). The Indonesian Navy (TNI AL), as a state element, bears a fundamental duty to maintain the defense and security of the country's maritime territory (Susilo et al., 2019b).

Collin (2015) suggests the need for an analysis of the common challenges faced by the Navy in the current landscape, including competing defense budget requirements, geopolitical uncertainties, and mounting strategic pressures. Susilo et al. (2019b) proffer that it is imperative to increase the allocation of the state budget towards the maritime sector, thereby enhancing the capabilities of the Indonesian Navy. Noraini et al. (2020), Furthermore, an analysis of the modernization of the TNI-AL is crucial to augment the capabilities of the Green Water Navy, enabling it to effectively respond to dynamic threats. A comprehensive approach to threat-based and capability-based planning and projections is necessary to develop the strength of the TNI-AL for the future (Laksmana 2014). Additionally, capability-based planning analysis is vital in preparing for future wars, as emphasized by Putra (2021). Therefore, research focusing on the analysis of the Indonesian naval capability development in addressing maritime security threats is essential to ensure its readiness and effectiveness.

The objective of this research is to analyze the sustainability framework of the naval capabilities required for national maritime security. This research holds significant importance for several reasons. Firstly, it aids in assessing the preparedness of the navy to effectively address various types of threats. A comprehensive analysis encompasses factors such as the navy's size, composition, and capacity to operate in diverse environments, including coastal zones and the high seas. Such information is vital for policymakers when making decisions regarding defense expenditures and resource allocation. Secondly, an analysis of naval capabilities assists in identifying potential vulnerabilities. By understanding the areas where the Navy may be susceptible, appropriate measures can be taken to address and mitigate those vulnerabilities. Lastly, analyzing naval capabilities contributes to enhancing stability and deterrence. A strong naval presence by countries within a region serves as a deterrent to potential aggressors, effectively preventing conflict escalation and fostering increased stability.

To accomplish our research objectives, we begin by establishing a sustainability framework for the development of naval capabilities. This framework consists of three subsystems: strength, capability, and pattern of operation. The study employs a qualitative descriptive statistical method approach, complemented by the system dynamics (SD) model built by STELLA 9. This combination allows us to identify key factors, interactions, and feedback mechanisms within the urban subsystems. Through simulations of various response policy scenarios, we can assess the impacts of these policies and discuss their implications. This analysis aims to provide valuable insights for the advancement of robust naval capabilities in ensuring national maritime security. The study is supported by an expert panel of academicians and practitioners from January 2022 to February 2023. with a focus on Indonesia's maritime security and naval capabilities as examples.

This research offers several contributions. First, focusing on the sustainability of naval capability by examining the dynamics of capability across various subsystems, bridging the gap between conceptual attributes and measurable variables the integrated model proposed in this study addresses challenges related to static variables encountered in naval capability modeling systems, and thereby introducing new solutions for sustainability assessment. Third, this paper contributes to the development of an operational approach to sustainability assessment. It combines system dynamics (SD) modeling with a participatory approach, building upon the research conducted by Susilo et al. (2019b).

2. Literature Review.

2.1. Maritime Security.

The definition and understanding of maritime security have undergone significant changes and lack a universally precise depiction; it depends on the specific context, viewpoint, and utilization (Desiana & Prisma, 2022). From a military perspective, maritime security has traditionally focused on national security issues to protect state sovereignty from armed attacks or other use of force and to protect state interests elsewhere. However, the scope of maritime security defense has broadened to cover a wider range of threats (Bueger, 2015).

Maritime security refers to the measures taken to safeguard ships, ports, and other maritime infrastructure from various threats, including piracy, terrorism, and smuggling (Chapsos & Malcolm, 2017; Susilo et al., 2020). Maritime security is shaped by the actions and patterns of interaction between the actors involved. The concept of maritime security lies between two perspectives (Bueger, 2015; Susilo et al., 2019a): 1) those employing traditional security frameworks, 2) those employing non-traditional frameworks. Another important aspect of maritime security is the role of navies and coastguards in protecting the waters of their countries.

The concept of national security is rooted in the traditional perspective, which focuses on preserving the state's survival. Within this context, naval power represents sea power and serves as the dominant force in maritime affairs. Hence, maritime security is closely associated with the utilization of naval power (Susilo et al., 2019a), aiming to enhance capacities and positions. The Navy assumes various roles, encompassing diplomacy, law enforcement, and military functions (Poerwowidagdo, 2015). Several threats pose challenges to maritime security (Chapsos & Malcolm, 2017). These include 1) threats of violence, such as piracy, sabotage, and terrorism targeting vital assets; 2) navigation threats, which involve risks and challenges

related to safe passage; 3) resource threats, encompassing damage and pollution to the sea and its ecosystem; and 4) threats to sovereignty.

2.2. Naval capability.

The Navy possesses diverse and extensive capabilities aimed at safeguarding a country's interests, both domestically and internationally. These capabilities encompass various aspects (Chapsos & Malcolm, 2017; Noraini et al., 2020; Singh & Verma, 2015):

a. Maritime Security: The Navy plays a crucial role in ensuring the security of a country's maritime borders. This involves tasks such as patrolling coastal waters, conducting surveillance operations, and intercepting any ships or vessels that may pose a threat to national security.
b. Power Projection: Another significant naval capability is its ability to project power globally. This enables the country to swiftly respond to potential threats and maintain a strong presence in strategic regions
c. Humanitarian Assistance and Disaster Relief: Besides their military responsibilities, Navies are often called upon to provide humanitarian aid and support during times of disasters or crises.
d. Additional Navy capabilities may involve conducting research and development in fields like oceanography and marine biology, enforcing international maritime laws, and supporting scientific explorations in remote areas of the world.

Naval capability is closely related to posture. Posture development is projected towards the maritime area, emphasizing an active defensive principle. This posture is specifically designed to tackle potential threats, address current challenges, and provide support to the defense forces. The components of posture include (Susilo et al., 2019a):

a. The Navy's strength is derived from various factors such as the modernization of main equipment and weapon systems, enhanced maintenance efforts, organizational development, support for facilities and infrastructure, professionalism, and the welfare of soldiers.
b. Capability: The capabilities of the Indonesian Navy are designed for intelligence, diplomacy, defense, security, regional empowerment, and support capabilities.
c. Power Projection: Navy deployment encompasses the organization, strength, and capability aspects. This is achieved through the establishment of a fleet command organizational structure, comprising centralized, territorial, and support unit forces.

3. Methods.

This study uses a descriptive statistical approach to analyze and interpret the data. Descriptive statistics are employed to summarize the pertinent aspects of the quantitative data concerning the evaluation of naval capability levels. The data collection process in this article involves two categories: primary data and secondary data. Primary data is sourced from experts in naval capabilities, including both practitioners and academics. The selection criteria for these experts are as follows: 1) Academics with at least a bachelor's degree (Khazaie & Khan, 2020); 2) Practitioners specializing in maritime security and the navy (Fallah & Ocampo, 2021); 3) Experts with a minimum of five years of work experience (Khalilzadeh et al., 2020); 4) Eight expert judgments, comprising four doctors and one doctoral student, as referenced in Almanasreh's (2019) research. Secondary data sources encompass various sources, such as news and information from print media, previous research findings from online sources, archives, regulations and policies, as well as official institutional documents and social media accounts.

This research took place in Jakarta and various deployment areas of naval bases in Indonesia, aiming to represent the sustainability of naval capabilities. The study was carried out between January 2022 and February 2023, utilizing a questionnaire distributed to experts, based on existing secondary data. The assessment of naval capabilities' sustainability has long been a topic of concern among researchers. In the context of Indonesia, there is a significant focus on studying the sustainability of naval capabilities due to the country's expansive territory and strategic global positioning. As a result, researchers perceive ample opportunities to contribute theoretically and explore potential avenues for advancement in this field.

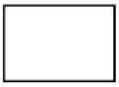
3.1. System dynamics.

Modeling serves as a valuable approach for addressing real-world problems, particularly when hands-on implementation or experimentation proves costly or challenging. By employing modeling techniques, one can effectively optimize their system before its actual deployment. The modeling process entails mapping real-world issues into a conceptual model, followed by analysis and optimization to derive implementable solutions (Sterman, 2010). Simulation, on the other hand, involves operating the system model itself. It serves as a preventive measure, allowing for the identification and mitigation of potential failures, unexpected bottlenecks, resource overuse, and optimization of overall system performance (Forrester, 2007).

The System Dynamics Society has defined System Dynamics (SD) as a method used to acquire knowledge and address complex relationships within systems. System dynamics was initially introduced by Jay W. Forrester in the 1950s as an approach to solve complex problems that arise because of trends, reasons and the influence of various variables within a device. The application of system dynamics was first explored in addressing control problems, such as fluctuations in stocks, volatility in business operations, and declining market shares. To represent the dynamics of a system, a stock-and-flow diagram is constructed, illustrating the simulation variables and parameterization. A model of the system is then prepared for simulation (Forrester, 2016). The variables within a dynamic structure are defined in Table 1.

System Dynamics models can be represented by a feedback diagram structure, commonly known as a causative Loop Diagram (CLD). This diagram illustrates the direction and po-

Table 1: Symbol of system dynamics.

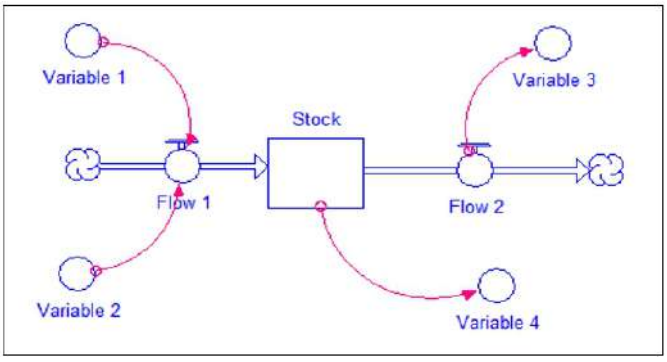
Variable	Symbol	Explanation
Level		Presenting the accumulated quantity that accumulates over time, its value can change in line with changes in the rate
Rate		Presenting a flow rate that can change the level value
Auxiliary		Presenting auxiliary variables containing formulations that can be input to the rate.

Source: Authors.

larity of variable flow modifications. The polarity of the flow can be either positive or negative. Another form of a diagram that collectively describes the structure of a system dynamics model is a flowchart. Flowcharts depict the relationships between variables, incorporating cause-and-effect diagrams with explicit, recognizable symbols for the involved variables (Sterman, 2018).

CLD is a visual language that connects various variables within a circular diagram. The use of arrows can indicate cause-and-effect relationships between variables. The source of the arrow represents the cause, while the arrowhead represents the effect Every modeler needs to have a thorough understanding of the processes occurring in the real world to ensure the logical consistency of the model with reality. This understanding is achieved by defining causal relationships between variables and distinguishing between dependent and independent variables (Schoenenberger et al., 2021). In this study, system dynamics analysis was conducted using STELLA 9 software.

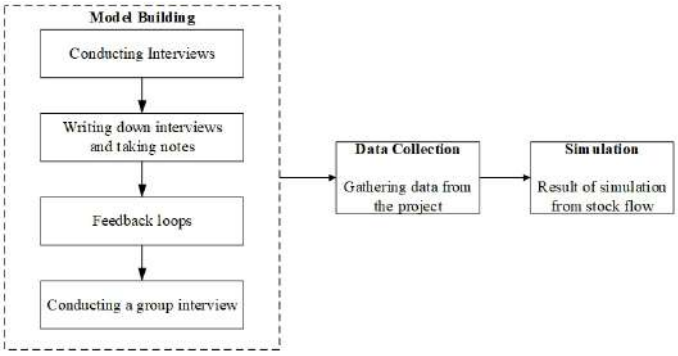
Figure 1: Minimal stock and flow diagrams in System Dynamics.



Source: (Forrester, 2009; Morshedi & Kashani, 2020; Schoenenberger et al., 2021).

In this paper, a systematic procedure was followed to ensure data saturation. Additionally, data was collected in a zigzag pattern and documents were analyzed. While literature review is a common approach for building System Dynamics (SD) models, it does not provide definitive results due to varying limitations

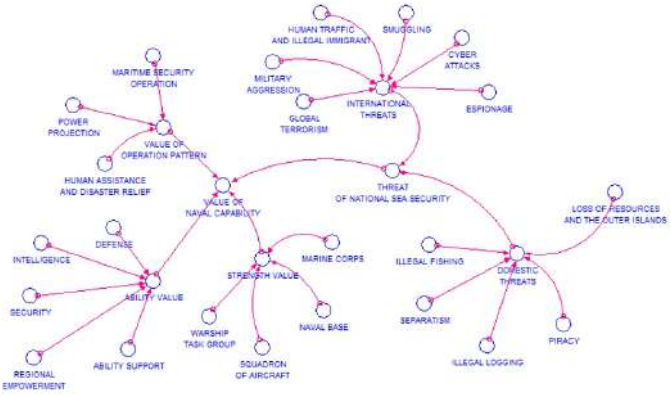
Figure 2: The flowchart of the study.



Source: Authors.

and potential inconsistencies across studies. The interviewees were selected theoretically to help the researchers construct the theory as well as possible. After that, a feedback loop consisting of causal relationships was extracted from the interviews, and a model was built using the identified relationships. Furthermore, group interviews were conducted with different experts to validate the model structure. Moreover, historical data from real projects were gathered. Finally, the model underwent a system dynamics validation test for further verification. The flowchart depicting the procedure followed in this study can be seen in Figure 2.

Figure 3: The causal feedback diagram of Naval Capability.



Source: Authors.

The feedback diagram serves as a representation of the interconnectedness of variables within the model, forming the foundation for simulation. To unveil the mechanism of interaction, a causal feedback diagram is created, focusing on the key variables, as shown in Figure 3. Constants are omitted from the diagram, and only the core variables are included. Figure 3 also shows that the four main variables build the dynamics of naval capability with several supporting sub-variables to produce a capability value against threats.

To ensure unbiased, strong, and dependable evaluations, the competence level is assessed by two separate teams comprising a maximum of four individuals each. These teams consist of both academic experts and practitioners. The assessment of

abilities is conducted using a Likert scale, ranging from one to five, where one represents an unsatisfactory level and five signifies an excellent level (as presented in Table 2). To determine the final assessment results for proficiency at level three, the average rating is computed by considering various assessment methods and evaluations.

Table 2: Scale on capability assessment.

Likert Scale	Descriptor	Attainment
5	Excellent	Mastery, excellent—Can lead changes, plan improvements, and grasp new techniques
4	Very Good	Proficient—Developed capability, can plan regular actions independently
3	Good	Developing capability above minimal or marginal can do basic things independently
2	Satisfactory	Just enough, minimal or marginal
1	Unsatisfactory	Lack of any capability

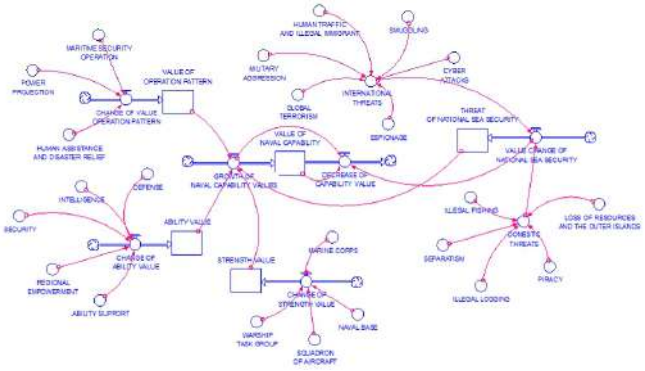
Source: Adopted from Subic et al. (2012) and Hong (2013).

Table 3: Naval capability level.

Level	Grade	Range	Description
5	Very capable	4.01-5	The predictable process dynamically changes and adapts to effectively meet relevant current and projected business goals
4	Highly capable	3.01-4	The established process performs consistently within defined limits to achieve its process outcomes
3	Barely capable	2.01-3	The managed process performs using a defined process that is based upon software engineering principles and capable of achieving its process outcomes
2	Not capable	1.01-2	The performed process executes in a managed fashion (planned, tracked, verified, and adjusted) based on defined objectives
1	Very not capable	0-1	The implemented process achieves its process purpose

Source: Adopted from Hong (2013) and Rout (1998).

Figure 4: The stock-flow model of Naval Capabilities.



Source: Authors.

A stock-flow model is a quantitative approach that can explain logical relationships, feedback patterns, and system control principles. Based on the causal feedback diagram, the variables are divided into stock, flow, and supplementary variables. Stock refers to variables that accumulate over time, flows refer to variables that change over time, and incremental variables refer to intermediate variables. Furthermore, flows impact stocks through inflows or outflows, establishing connections between various stocks within the system (Li et al., 2020).

The stock-flow model allows investigation and visualization of the effects of different measures (Sterman, 2010). The meaning of the shape in the stock-flow model is shown in Figure 1. Within the System Dynamics (SD) model, there are primarily six types of variables: level variables, rate variables, auxiliary variables, constants, flow variables, and sink variables. Level variables and rate variables hold the most essential information. Furthermore, rate variables denote cumulative quantities, while level variables represent the rate at which quantities change as they accumulate. Constants, on the other hand, remain constant over time.

Based on the causal feedback diagram, this study develops a stock-and-flow model to assess the Indonesian Naval capability in addressing sea security threats. The model incorporates variables represented in Figure 4. They are Operation Pattern, Ability, Strength, and the threat to national sea security. Each level variable encompasses sub-variables that represent influential factors. For instance, the Operation Pattern variable consists of three sub-variables: maritime security operation, power projection, and humanitarian assistance and disaster relief. The stock-and-flow model employed in this study captures the dynamic process of Indonesian Naval capabilities. Another variable is capability value, which is measured and simulated to make the SD model closer to the real situation.

4. Result and Discussion.

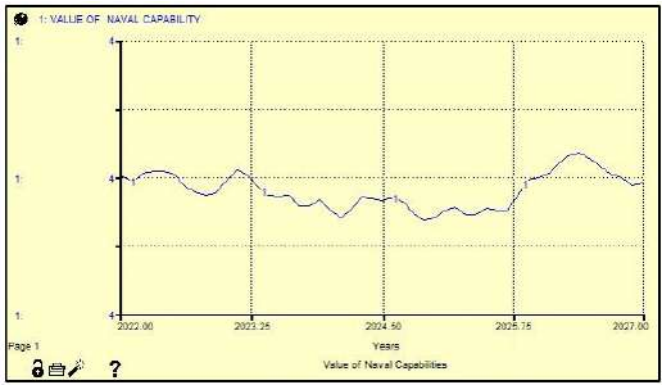
Scenario analysis in system dynamics modeling (SDM) is a valuable tool for exploring a spectrum of potential future outcomes, based on different policies and actions. In SDM, the values of variables and parameters can be modified to depict various actions and scenarios. The simulation results will vary based on these different inputs (Bottero et al., 2020).

To assess naval capabilities, the framework proposed in this study was tested using the example of Indonesia's national maritime security and naval capabilities. The Indonesian Sea holds significant global importance due to its vast size and its crucial role in international trade, national defense, and natural resources. Positioned between Asia and Australia, and the Pacific Ocean and the Indian Ocean, it occupies a strategic location (Susilo et al., 2020). The Indonesian Sea is susceptible to various crimes and disasters. Criminal activities at sea encompass theft, robbery, drug smuggling, human trafficking, and ship piracy (Wahyudi et al., 2019). Furthermore, Indonesia's marine areas frequently experience natural disasters such as tsunamis, earthquakes, and storms.

Enhancing naval capabilities against these threats has emerged as a pressing challenge for achieving regional stability. To simulate the dynamic process of naval capability in addressing national maritime security threats, this paper utilizes STELLA 9 software. From 2022 to 2027, the naval capability value fluctuates between 3.77 and 3.78, signifying a highly capable (level

4). This value is dynamic, influenced by environmental and internal factors, with a model range from 0 to 5.

Figure 5: The output value of naval capabilities in 5 years.



Source: Authors.

Figure 5 illustrates the progressive growth of naval capabilities. From 2022 to 2024, there will be a slight decline in naval capabilities. This decline can be attributed to dynamic and uncertain factors, including external and internal threats. However, the development of various strengths and the incorporation of additional main equipment and weapon systems and operational patterns will enhance defense capabilities. Consequently, it is crucial to implement a strategy that combines delaying tactics with the continuous enhancement of naval power projection capabilities to effectively address existing maritime security threats.

President Jokowi has put forward several proposals to implement specific aspects of the doctrine, which involve initiatives like constructing ports and enhancing naval capabilities (Sambhi, 2015). At the same time, the actions undertaken by stakeholders in response to threats, including the development and deployment of naval capabilities, also impact the parties involved. These stakeholders share common concerns regarding territorial control, resource management, and national maritime security, as highlighted by research conducted by Sakuwa (2017). Safeguarding and improving maritime communication routes through enhancing naval capabilities have gained significant importance on the national strategic agenda.

Furthermore, between 2024 and 2027, the naval capability is projected to experience a gradual increase while remaining within the range of 3.78, indicating a highly capable level. The ongoing development and construction of naval forces are expected to be completed by 2024, enabling their deployment in alignment with the existing threat capacity in national waters. There are efforts to assess foreign naval capabilities, explore opportunities to assert presence and challenge foreign military access and operations. Military coercion tactics involve activities such as monitoring, interfering with, and obstructing foreign military operations in international waters, all aimed at maintaining regional stability (Patalano, 2018). The development and establishment of naval capabilities, along with the formation of asymmetrical forces, can confer advantages. Certain countries perceive these actions as necessary to assert territorial claims and safeguard national interests in maintaining their maritime security (Emmers, 2009).

4.1. Scenario Analysis.

The next step of this paper considers different scenarios: inertia and a strategic scenario. The inertia assumes that there is an increase in threats, while the strategic scenario is an action that may be taken when the threat increases by increasing the pattern of operations, capabilities, and strength. To represent these scenarios in the system dynamics model, different parameter values have been assigned: (1) the threat level can reach up to level 5, and (2) strategic measures are implemented to address the increased threats.

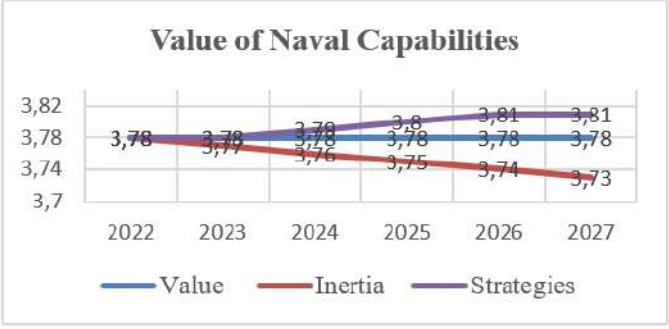
In detail, low values have been set for the inertia scenario, to represent a no-intervention policy. On the other hand, moderate values have been set for this parameter to represent the actions of strategic scenarios in the HR model. Scenario simulations have been carried out for 5 years. This simulation has been developed for variables identified as threats. The main objective is to examine the possibility of its influence over time and how it affects the naval capability in dealing with evolving threats. Table 4 and Figure 6 illustrate the simulation, providing a visual comparison of the scenarios' evolution over time.

Table 4: Scenarios for the simulation of naval capabilities.

Year	Value	Inertia	Strategies
2022	3.78	3.78	3.78
2023	3.78	3.77	3.78
2024	3.78	3.76	3.79
2025	3.78	3.75	3.8
2026	3.78	3.74	3.81
2027	3.78	3.73	3.81

Source: Authors.

Figure 6: Histogram of Scenario results for naval capabilities.



Source: Authors.

In the first scenario (inertia), the threat level increases, but no action is taken for 5 years. As a result, there is a declining trend in the naval capabilities value. The threat level is assumed to reach level 5, with values ranging from 4.2 to 4.5, which has

a negative impact on the capability value, causing it to decrease from 3.78 to 3.73. However, even with this decrease, the capability value remains at a highly capable level, indicating a significant level of capability. Naval capabilities play a significant role in enhancing the influence of maritime powers and their engagement in global affairs. However, it also has weaknesses, including the potential for increased uncertainty and the risk of miscalculations (Gartzke & Lindsay, 2020). To effectively address these challenges, it is recommended to develop naval capabilities that can address a wide range of missions, spanning from modern conflicts to non-war military operations (Olivier & Balestrini-Robinson, 2014).

In the second scenario, the threat level is increased to level 5, accompanied by strategic actions such as enhancing strengths, capabilities, and operational patterns. As a result, there is a positive trend in naval capabilities, with the value increasing from 3.78 to 3.81. continues to experience an upward trend in level 4 (highly capable). However, Indonesia acknowledges that its current naval capabilities are insufficient to fully address the security challenges it faces, both internally and externally (Noraini et al., 2020). Displaying naval capabilities through patrols and exercises has been employed as a measure to counter threats to national maritime security (Kipgen, 2018). In the future, stakeholders can take advantage of their strategic territorial location and increase their naval capabilities to prevent aggressive actions from countries in the Pacific (Paszak, 2021). Strengthening naval capabilities is crucial for power projection in the Indian Ocean region and to address development and national security requirements (Singh & Verma, 2015).

Conclusions

Sustainability in the development of naval capabilities toward national maritime security is a fundamental aspect of dealing with future wars. Analyzing the framework through scenarios and simulations allows for a comprehensive assessment. In this context, Indonesia's national maritime security and naval capabilities serve as a practical example to test the proposed framework.

According to the study findings, the naval capability value remains consistently high from 2022 to 2027, ranging from 3.77 to 3.78, indicating a highly capable status. From 2022 to 2024 (24 months), there is a slight decline in naval capabilities. However, between 2024 and 2027 (36 months), there is a gradual increase in naval capability, although it remains within the highly capable range of 3.78. It is anticipated that the ongoing development and construction of naval forces will be completed by 2024, enabling their deployment in alignment with the existing threat capacity in the national maritime domain.

In the context of inertia, the threat is assumed to increase significantly to level 5, ranging from 4.2 to 4.5. As a result, the naval capability value decreases from 3.78 to 3.73. Despite this decline, the naval capability remains at a highly capable level 4. On the other hand, in the second scenario, the increase in the threat value to level 5 is accompanied by strategic actions, including the development of strengths, capabilities, and patterns of operations. As a result, there is an upward trend in the value of naval capabilities, rising from 3.78 to 3.81. This trend indicates a continuous improvement at the highly capable level 4.

Limitation & Future Work.

There are several limitations in this research. Firstly, it did not consider the influence of economic growth and the development of the defense industry on the trend of changing naval capabilities, particularly due to the COVID-19 pandemic. Future research could incorporate economic variables and the defense industry as well as global impacts such as the Ukrainian War. Second, this study selected several important variables to develop the model and may miss some critical variables. Each pair of variables requires a single formula or function, while some variables are difficult to measure. In the future, the SD model can be used to analyze more system issues and users should increase its validity, and establish causal relationships. Third, there is still limited spatial scale in the simulation and impact evaluation of the strategy. A potential solution is to integrate a combined approach that evaluates the naval capability development strategy's impact on both tangible and intangible national maritime security threats.

Acknowledgements.

This study was supported by Brawijaya University and Indonesia Naval Technology College.

References.

Almanasreh, E., Moles, R., & Chen, T. F. (2019). Evaluation of methods used for estimating content validity. Research in Social and Administrative Pharmacy, 15(2), 214–221. https://doi.org/10.1016/j.sapharm.2018.03.066.

Bottero, M., Datola, G., & de Angelis, E. (2020). A system dynamics model and analytic network process: An integrated approach to investigate urban resilience. Land, 9(8), 24–26. https://doi.org/10.3390/LAND9080242.

Bueger, C. (2015). What is maritime security? Marine Policy, 53, 159–164. https://doi.org/10.1016/j.marpol.2014.12.005.

Chapsos, I., & Malcolm, J. A. (2017). Maritime security in Indonesia: Towards a comprehensive agenda? Marine Policy, 76(April 2016), 178–184. https://doi.org/10.1016/j.marpol.2016.11.033.

Collin, K. S. L. (2015). What next for the indonesian navy? Challenges and prospects for attaining the minimum essential force by 2024. Contemporary Southeast Asia, 37(3), 432–462. https://doi.org/10.1355/cs37-3e.

Desiana, R., & Prima, S. C. (2022). Cyber security policy in Indonesian shipping safety. Journal of Maritime Studies and National Integration, 5(2), 109–117. https://doi.org/10.14710/jmsni.v5i2.13673.

Emmers, R. (2009). Geopolitics and maritime territorial disputes in East Asia. In Geopolitics and Maritime Territorial Disputes in East Asia. https://doi.org/10.4324/9780203875018.

Fallah, M., & Ocampo, L. (2021). The use of the Delphi method with non-parametric analysis for identifying sustainability criteria and indicators in evaluating ecotourism management: the case of Penang National Park (Malaysia). Environment Systems and Decisions, 41(1), 45–62. https://doi.org/10.1007/s10669-020-09790-z.

Forrester, J. (2009). Some basic concepts in system dynamics. Sloan School of Management, . . . , 1–17. http://www.systems-modelbook.org/uploadedfile/238_63f73156-02df-4d87-b0c6-c2-86a7beec26_SomeBasicConcepts.pdf.

Forrester, J. W. (2007). System dynamics - The next fifty years. System Dynamics Review, 23(2–3), 359–370. https://doi.org/10.1002/sdr.381.

Forrester, J. W. (2016). Learning through System Dynamics as Preparation for the 21st Century. System Dynamics Review, 32(3–4), 187–203. https://doi.org/10.1002/sdr.1571.

Gartzke, E., & Lindsay, J. R. (2020). The Influence of Sea Power on Politics: Domain- and Platform-Specific Attributes of Material Capabilities. Security Studies, 29(4), 601–636. https://doi.org/10.1080/09636412.2020.1811450.

Hong, W. P. (2013). Machine capability index evaluation of machining center. Journal of Mechanical Science and Technology, 27(10), 2905–2910. https://doi.org/10.1007/s12206-013-0801-8.

Joakim, E. P., & Mortsch, L. (2016). Using system dynamics to model social vulnerability and resilience to coastal hazards Greg Oulahen Deborah Harford and Yaheli Klein Kirstin Damude Kathy Tang. Int. J. Emergency Management, 12(4), 366–391.

Khalilzadeh, M., Katoueizadeh, L., & Zavadskas, E. K. (2020). Risk identification and prioritization in banking projects of payment service provider companies: an empirical study. Frontiers of Business Research in China, 14(1). https://doi.org/10.1186/s11782-020-00083-5.

Kipgen, N. (2018). Asean and China in the South China sea disputes. Asian Affairs, 49(3), 433–448. https://doi.org/10.1080/03068374.2018.1487691.

Kipgen, N. (2021). Indonesia: A Reluctant Participant in the South China Sea Disputes. Strategic Analysis, 45(2), 116–127. https://doi.org/10.1080/09700161.2021.1891762.

Laksmana, E. A. (2014). Rebalancing Indonesia's naval force. Naval Modernisation in South-East Asia: Nature, Causes and Consequences, 175–203.

Li, G., Kou, C., Wang, Y., & Yang, H. (2020). System dynamics modelling for improving urban resilience in Beijing, China. Resources, Conservation and Recycling, 161(June), 104954. https://doi.org/10.1016/j.resconrec.2020.104954.

Maulana, A. A. (2022). Gunboat Diplomacy in Natuna Waters from 2010-2020: Indonesia's Deterrence in South China Sea Conflict. Insignia: Journal of International Relations. http://jos.unsoed.ac.id/index.php/insignia/article/view/4550.

Morshedi, M. A., & Kashani, H. (2020). A system dynamics model to evaluate the housing market response to vulnerability reduction promotion policies. International Journal of Disaster Risk Reduction, 101438. https://doi.org/10.1016/j.ijdrr.2019.101438.

Noraini, Z., Muhamad Nazrul, B., & Azrul Azlan, A. R. (2020). The Modernisation of Indonesian Naval Forces in Jokowi Era. Malaysian Journal of History, Politics & Strategic Studies, 47(April), 1–23.

Olivier, J. P., & Balestrini-Robinson, S. (2014). Capability-based system-of-systems approach in support of complex naval ship design. CEUR Workshop Proceedings, 1234, 59–70.

Paszak, P. (2021). The Malacca Strait, the South China Sea and the Sino-American Competition in the Indo-Pacific. Journal of Asian Security and International Affairs, 8(2), 174–194. https://doi.org/10.1177/23477970211017494.

Patalano, A. (2018). When strategy is 'hybrid' and not 'grey': reviewing Chinese military and constabulary coercion at sea. Pacific Review, 31(6), 811–839. https://doi.org/10.1080/09512748.2018.1513546.

Poerwowidagdo, S. J. (2015). Blue Ocean Strategy in Managing Maritime Security Sapto. Jurnal Pertahanan, 1(1), 13–26.

Putra, H. (2021). An Analysis on the Navy's Defense Planning based on the potential phenomenon of Arms Races in Southeast Asia and the Minimum Essentials Force Strategy. Technium Soc. Sci. J., 21(July), 862–876. https://heinonline.org/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/techssj21&section=76.

Rismana, H., M, S., Octavian, A., & Mahroza, J. (2021). The Evolution Of Indonesian Archipelagic Defence From 1945 To 1990s. Nat. Volatiles & Essent. Oils, 8(6), 5844–5857.

Rochwulaningsih, Y., Sulistiyono, S. T., Masruroh, N. N., & Maulany, N. N. (2019). Marine policy basis of Indonesia as a maritime state: The importance of integrated economy. Marine Policy, 108(June), 103602. https://doi.org/10.1016/j.marpol.2019.103602.

Rout, T. P. (1998). SPICE and the CMM : is the CMM compatible with ISO / IEC 15504. AquIS'98, January 1998, 12.Sakuwa, K. (2017). The Regional Consequences of Territorial Disputes: An Empirical Analysis of the South China Sea Disputes. Journal of Asian Security and International Affairs, 4(3), 316–336. https://doi.org/10.1177/2347797017732228.

Sambhi, N. (2015). Jokowi's 'Global Maritime Axis' Smooth Sailing or Rocky Seas Ahead? Security Challenges, 11(2), 39–55. https://www.jstor.org/stable/26465437.

Schoenenberger, L., Schmid, A., Tanase, R., Beck, M., & Schwaninger, M. (2021). Structural Analysis of System Dynamics Models. Simulation Modelling Practice and Theory, 110(April), 102333. https://doi.org/10.1016/j.simpat.2021.102333.

Singh, B., & Verma, N. (2015). India's Needs and Naval Capabilities: A Symbiotic Relationship. Journal of Asian Security and International Affairs, 2(1), 52–74. https://doi.org/10.1177/2347797014565294.

Sterman, J. (2018). System dynamics at sixty: the path forward. System Dynamics Review, 34(1–2), 5–47. https://doi.org/10.1002/sdr.1601.

Sterman, J. D. (2010). Does formal system dynamics training improve people's understanding of accumulation? System Dynamics Review, 26(4), 316–334. https://doi.org/10.1002/sdr.447.

Subic, A., Shabani, B., Hedayati, M., & Crossin, E. (2012). Capability framework for sustainable manufacturing of sports

apparel and footwear. Sustainability, 4(9), 2127–2145. https://-doi.org/10.3390/su4092127.

Susilo, A. K., Ciptomulyono, U., Putra, I. N., Ahmadi, & Suharyo, O. S. (2019a). Navy development strategy to encounter threat of national maritime security using SWOT-fuzzy multi criteria decision making (F-MCDM). Journal of Maritime Research, 16(1), 3–16.

Susilo, A. K., Ciptomulyono, U., Putra, N., Ahmadi, A., & Suharyo, O. (2019b). Navy ability development strategy using SWOT analysis-interpretative structural modeling (ISM). Strategic Management, 24(1), 30–40. https://doi.org/10.5937/-straman1901030s.

Susilo, A. K., Putra, I. N., Ahmadi, & Suharyo, O. S. (2020). Analysis of national maritime security strategy as an effect of regional development using SWOT, fuzzy multi criteria decision making (FMCDM) and borda. International Journal of Operations and Quantitative Management, 25(3), 153–174.

Teniwut, W. A., Hamid, S. K., & Makailipessy, M. M. (2019). Selecting top fisheries sub-sector in each sub-district for sustainable development of archipelagic region in Indonesia: A hybrid fuzzy-MCDM approach. Decision Science Letters, 8(4), 393–410. https://doi.org/10.5267/j.dsl.2019.6.001.

Wahyudi, A., Wandawa, G., Samiaj, R., & Susilo, A. K. (2019). Strategic Development The Capability of Indonesian Warship (KRI) dr. SOEHARSO-990 for Combine Operation of Human Assistance/Disaster Resilience in Sotheast Asian Regional. Journal of Defense Resources Management, 10(2), 73–91. https://search.proquest.com/docview/2339150475?account-id=17242.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 104–109

ISSN: 1697-4840, www.jmr.unican.es

Innovative Design Idea for Smart Safety Helmet for Seafarers

Tushant Yadav[1], Subham Jha[1], Yash Gupta[1], Sanjay M. Puranik[1,*]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 24 Jun 2023;
accepted 16 Jul 2023.

Keywords:
Technological innovation, safety culture, man overboard.

ABSTRACT

This paper aims at presenting a possible idea for enhancing the safety culture that has always been an important aspect at maritime industry particularly man overboard situation and while during ships operations. This helmet can help the mariners to detect all the possible red signals onboard. Red signals which include, man overboard and any kind of health issues onboard. The authors have tried using the evolving modern technologies to contribute towards the safety measures of the industry. An attempt has been made to bring up the prototype with required research which can be helpful in increasing the safety measures just by wearing safety helmet. Interestingly, this smart safety helmet is capable of sending signals to various sections like Bridge to alert other crews about some unwanted incident and accidents etc. for quick rescue.

1. Introduction.

Safety in maritime industry holds paramount interest and is of utmost importance, majority of the accidents happen due to the intentional/unintentional carelessness of the crew members, improper monitoring or insufficient information about the situation are the contributing factors.

Work accidents, according to Heinrich 88% are caused by human factors so that they can be prevented, so improving the behavior of workers becomes very important. (Husan, 2019). Helmet or Protective Cap is used to make head protection from exposure to hazards such as falling objects or exposure to electrical hazards. Many studies are carried out on the topic of seafarer's safety issues (Akindehim, 2015). It is observed many times that despite vital role of safety helmet many seafarers tend to take off their helmet because of discomfort caused by weight and higher temperatures in engine room and deck. Wearing a safety helmet can reduce the risk resulting in head injury. (Zhong, 2019). ILO code of practices published in the year 2019 on safety and health in ship building and ship repair proposed lots of very useful safety norms. (ILO,2019). According to Marine Insight (Mohit, 2019) during every shipboard operation, the three prime factors that should be focused on by the onboard personnel are the safety of the crew, safety of the ship and cargo, and protection of marine environment. However, under some unfortunate incidences such as man overboard etc. identifying a missing person, even though wearing safety tools, is extremely difficult, particularly at night time.

In this paper we emphasize the new design of helmet not just as a head protective device but also gives alert messages by the use of different sensors to the navigational bridge in case of accident such as man overboard. (kamal and Selmy, 2016). To overcome this issue and to improve the ship's safe operation and prevent the loss of life at sea, this paper proposed a state-of-the-art method based on Arduino uno microcontroller board based on ATmega328P (Arduino store)) model of smart safety helmet for automatic and real-time detection of seafarer?s health for working environment and identifying his GPS location. Arduino Uno is an open-source microcontroller board based on the processor ATmega328P. There are 14 digital I/O pins, 6 analog inputs, a USB connection, a power jack, an ICSP header, and a reset button. It contains all the necessary modules needed to support the microcontroller. Just plug it into a computer with a USB cable or power it with an adapter to get started. (Flyrobo blog).

This paper aims to reduce many such risks such as man over board, consumption of alcohol etc. by making use of a smart

[1]Indian Maritime University, Navi Mumbai Campus, Navi Mumbai.
[*]Corresponding author: Sanjay M. Puranik. E-mail Address: smpuranik@imu.ac.in.

safety helmet that could effectively monitor and send alarms to alert the bridge of untoward incidence to enhance safety. This paper comprises of the details of such a prototype developed by the author. We used various types of sensors fitted inside the helmet which detects many parameters while working on board.

According to safety precautions onboard the ship a person working on deck is supposed to wear a safety helmet at all the times as a personal protective equipment (SHM ShipCare, 2018). Hence, adding smart features to the traditional helmet would solve the monitoring and alarm raising problems on board ship. The embedded sensors would trigger the alarm on the bridge which is always manned. The helmet would be connected to the monitoring unit through Wi-Fi direct/blue tooth or GPS system. Since each unit will have an assigned identity code every individual would be identifiable when on deck.

Any error or message received from the helmet will be displayed here along with the crew members name and this will activate the desired buzzers and alarms to draw the attention of the Officer-on-watch.

Such smart safety helmet can be used in many areas such as onboard a ship, dock labors, dry docking and ship building and ships are repairing and repairs of the ship and many other places including mining railway workers etc.

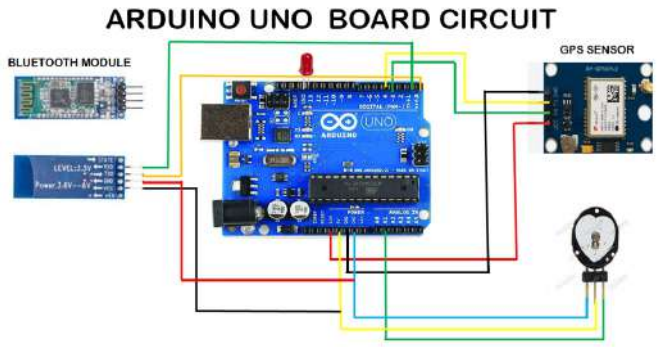
2. Designing of the Safety helmet.

Smart helmet comprises of following components:

A Safety helmet, microcontroller Unit with Wi-Fi/blue tooth and GPS, Alcohol and Gas sensors, Pulse sensor, accelerometer sensor, water sensor, GPS module and Li-Po battery (9 V).

Block diagram of the circuit components is shown in the Figure 1. Water and alcohol sensors and connections are shown in Figure 2.

Figure 1: Lay out of sensors and Arduina uno.



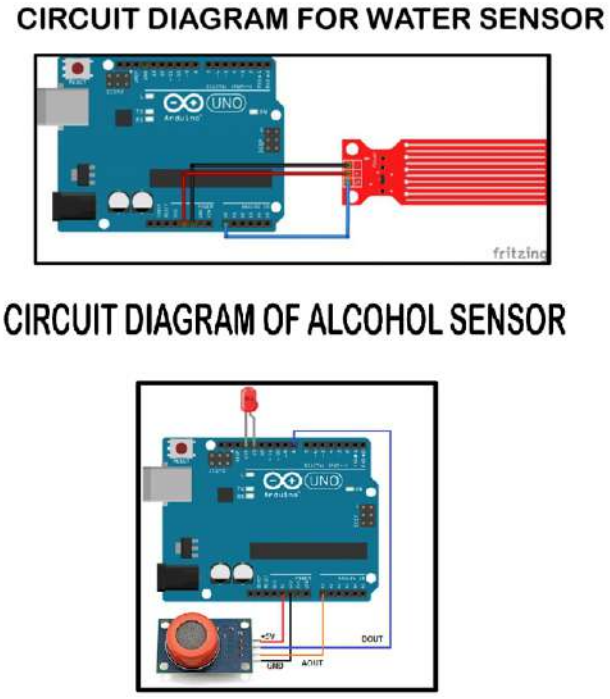
Source: Arduino Uno JavaT point.

3. Working of the Smart Helmet.

(a) Alcohol/Toxic gas Sensor.

Alcohol sensors such as MQ3 used here can measure as low as 0.04 mg/liters of alcohol presence. This sensor detects the

Figure 2: Water and alcohol sensor connections.



Source: Circuit digest.

presence of alcohol in the air as well as its concentration. The MQ3 sensor is one of the most widely used in the MQ sensor series. It is a MOS (Metal Oxide Semiconductor) sensor. Metal oxide sensors are also known as Chemiresistors because sensing is based on the change in resistance of the sensing material when exposed to alcohol. The MQ3 alcohol sensor operates on 5V DC and consumes approximately 800mW. It can detect alcohol concentrations ranging from 25 to 500 ppm.(Patel, 2022). It would be able to sense from the breath of the crew member. If the person is found drunk, the helmet will send a message to the bridge and the LED on helmet will glow along with the buzzer sound to alert the bridge and other personnel in the vicinity. This will be able to reduce the accidents caused by drunken crew members and hence in compliance to the no drinking policy of the shipping companies.

The Analog output pin (AOUT) gives Analog Voltage Output in direct ratio to the amount of alcohol detected by the sensor which then triggers the Digital Output(high/low) based on the values received though the analog output. The Higher the amount of alcohol in a person's breathe the higher will be its analog output and viceversa [1]. Once the Analog Value crosses its set threshold limit the digital output is triggered 'high' and the sensor will next activate the buzzer on the bridge and on the helmet as a warning signal.

The Toxic Gas sensors can detect gases like Ammonia, Benzene, Methane, Hexane, LPG and Carbon Monoxide thus giving an early warning to the person wearing it along with alerting the bridge. For the demonstration of concept MQ3, MQ135 sensors were used. There are sensors capable of detecting as low as 20 ppm of alcohol. Thus, a system with foolproof de-

tection of alcohol is viable. The Alcohol and Toxic Gas sensors housed close to Mouth.

The actual photograph of smart helmet and its use by wearing on head is depicted in the following figures:

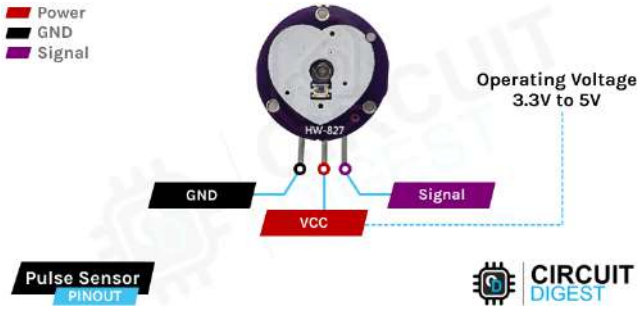
Figure 3: Authors prototype of smart safety helmet.

Source: Authors.

(b) Pulse Sensor. The pulse sensor interface, MAX30102, is a well designed plug and play heart rate sensor for Arduino.

The pulse sensor comes with a flat ribbon cable with three male header connectors. The Pin out of the Pulse sensor is given below.

Figure 4: Pulse Sensor Pinout.



Source: Circuit digest.

An optical pulse sensor shines a green light with 550 nm wavelength through the skin and measures the reflected light; this method of pulse detection is called Photoplethysmogram. (Das, 2022)

This pulse sensor used to read the pulse of the person wearing the helmet. The LED on the front side of the sensor is to be placed on a vein (here the ear tips). Veins have blood flow inside them only when the heart is pumping thus the pulse sensor monitors this blood flow to monitor the heartbeat. According to the data received by this sensor various aspects about a person?s health in general could be calculated like sleep tracking, anxiety, and consciousness. An example of received data is depicted in screen shot below.

Benefits of pulse sensor.

It would confirm if the crew is **wearing a helmet** since it starts getting the pulse input from the nerves near our ears/from the smart watch and hence ensure compliance of safety regulations.

If it finds the pulse rate of the person is too low or too high, during enclosed space operations, it will alert the officer (both him and the watch keeping officer on bridge) of his **abnormal health**. If it fails then it will direct the ESP8266 WIFI module on the helmet to send a message to the bridge indicating his retarding wellness during the operation and needs immediate rescue.

This will then combine the data from the toxic fumes sensor so as to **warn the incoming rescue party** about the atmosphere in the enclosed space.

(c) Accelerometer Sensor.

Accelerometer is an electromechanical device that measures the force of acceleration due to gravity in g unit. It can be used in applications requiring tilt sensing. The ADXL335 measures acceleration along X, Y and Z axes and gives analog voltage output proportional to the acceleration along these 3 axes.

An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static (gravitational) or dynamic - caused by moving or vibrating the accelerometer. These forces can be detected based on Axis-wise rotations. So, we try to set a parameter that after a specific Rotation (i.e., how much does the person receives an impact after falling in an accident) it will detect an accident.

The basic work of the accelerometer in the helmet is to detect a fall i.e.,it calculates a fall based on the acceleration in all the three directions- x, y and z axis.

Once fall is detected either by free fall due to gravity method in the accelerometer or by change in the angle of the helmet method it sends out this data to the bridge alarming the officer on watch to take adequate actions immediately. The prototype has been adequately programmed to detect such cases (e.g., Man overboard) using the free fall and direction angle algorithm**.**

There have been a lot of cases where the person has become overboard and no one was able to detect this for hours resulting in never finding the person again, or maybe finding him dead because of drowning in the sea or animal attacks. Using the helmet this can be easily countered as the detection will be done as soon as the man falls overboard and hence the crew members will have enough time to take proper and effective actions.

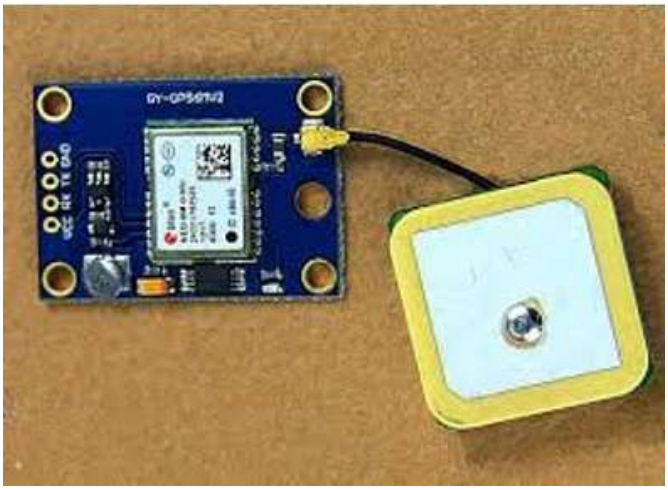
The helmet will also have an additional water sensor so as to accurately detect that it Isa case man overboard. considering the situation where maybe by some error the buzzer goes on or where the crew member has fallen on the deck and is in no danger i.e. the fall isn't crucial then he will have a kill switch mechanism on the helmet to kill the buzzer alarm to prevent misinformation.

(d) GPS module sensor.

The purpose of inclusion of GPS sensor in the smart helmet is to identify the accurate position of a person at the time of fall so that he can be rescued immediately. GPS sensors can provide real time position data in Arduino projects. By detecting latitude, longitude, altitude, velocity, and heading, they?re an indispensable tool for autonomous working and other devices where the global position needs to be known. This sensor module can easily be interfaced it with Arduino to obtain GPS parameters such as latitude, longitude, altitude date, time, speed,

satellites, etc. GPS sensor used in this work is shown below.

Figure 5: GPS sensor.



Source: AmateurRadio.

This GPS module consists of 4 pin, namely, GND, Tx, Rx and Vcc along with antenna (microcontroller lab).

(e) Procedure of Sensors activation in a sequence.

Person wears the helmet alcohol check, if negative continue pulse rate monitoring on toxic gas monitoring on accelerometer active throughout to detect fall water sensor backup for accelerometer.

Accident detection and related actions: fall detected; sound bridge alarm man overboard alarm and lights activated pulse rate error or toxic gas detection activate bridge alarm and call rescue team false alarm sounded due to error person uses the kill switch on helmet to kill alarm.

4. Features of this design.

Some of the design features are listed below:

- Effective placing of all sensors.
- Waterproof casing for battery and board.
- Kill switch on the sides.
- LEDS and buzzers inbuilt with no additional changes to the effective strength of the helmet.
- Modified design to also accommodate the **face shield / mask**.

The Prototype was fabricated using components locally procured. It is possible to engineer the entire circuit as a single hermetically sealed module and shaped it to sit within the helmet without interfering with its basic safety function. The cost of system could be lowered substantially when produced on economic scales. Also sensors with lower detection threshold can be incorporated at marginally higher cost.

All the sensors are interfaced with Arduino Uno microcontroller after necessary coding programs separately for each sensor. Coding programming is illustrated below.

5. Results and Conclusion.

The experiments were performed using prototype and observations are shown in the Table 1 and Table 2 below. Note that Table 1 gives the information regarding pulse rate, GPS location, time of fall, date and direction of fall and speed of the movement of the crew before and after the fall, if it happens. Table 2 shows actual data obtained during the tests.

Table 1: Data to be obtained at different instances.

MONITOR READING BEFORE FALLING	
PULSE RATE	Normal (60-100)
ALCOHOL LEVEL	No alcohol
GPS LOCATION	LIVE - Latitude/Longitude
TIME STAMP	Time of reading
DATE	Date of reading
DIRECTION	Direction of movement of person
SPEED	Speed of movement
ACCELEROMETER READING	No vertical motion detected
MONITOR READING DURING FALL	
PULSE RATE	Slightly higher than normal
ALCOHOL LEVEL	No alcohol
GPS LOCATION	LIVE - Latitude/Longitude
TIME STAMP	Time of reading
DATE	Date of reading
DIRECTION	Direction of movement of person
SPEED	Speed of movement
ACCELEROMETER READING	Vertical motion detected
MONITOR READING AFTER FALL	
PULSE RATE	Slightly higher than normal
ALCOHOL LEVEL	No alcohol
GPS LOCATION	LIVE - Latitude/Longitude
TIME STAMP	Time of reading
DATE	Date of reading
DIRECTION	Direction of movement of person
SPEED	Speed of movement
ACCELEROMETER READING	**Man overboard**

Source: Authors.

Table 2: Data obtained After Testing of smart safety helmet.

TEST – I	
PULSE RATE	96
ALCOHOL LEVEL	No alcohol
GPS LOCATION	19.0179° N, 73.0072° E
TIME STAMP	11:11
DATE	21/12/2022
DIRECTION	Towards North
SPEED	3 km/h
ACCELEROMETER READING	No vertical motion detected
TEST – II	
PULSE RATE	85
ALCOHOL LEVEL	No alcohol
GPS LOCATION	19.0179° N, 73.0072° E
TIME STAMP	12:34
DATE	28/12/2022
DIRECTION	Towards North
SPEED	2.5 km/h
ACCELEROMETER READING	vertical motion detected
TEST – III	
PULSE RATE	105
ALCOHOL LEVEL	No alcohol
GPS LOCATION	19.0179° N, 73.0072° E
TIME STAMP	16:35
DATE	17/02/2023
DIRECTION	Towards North
SPEED	3 km/h
ACCELEROMETER READING	No vertical motion detected

Source: Authors.

It should be underlined that all these test readings of the prototype may slightly vary depending upon the Prevailing conditions and circuit components.

In the test results obtained as above, Direction gives the information of man overboard after the fall towards the North direction in this case. Speed suggest that, at what speed the person is moving in that direction and Accelerometer reading suggests vertical motion. Other data has its usual meaning. Note that GPS location shown is same since tests were performed in the campus.

This paper presents the results obtained with this prototype are very satisfactorily and expected.

Reducing the chances of accidents and taking effective actions without wasting precious time is essential way of preventing damage to life and property of a vessel while at sea. This paper thus explores the idea of using an advanced advanced technology and sensors in designing helmet that could cater to modern needs onboard. It comprises of various sensors which collect real time data of the crew member and alert others onboard as soon as any unfavorable situation comes up. This paper has outlined the major advancements that are possible in a safety helmet and has tried to promote a safe work environment through innovative ideas by making the right use of currently available technology.

5.1. *Coding for the Arduino Uno board.*

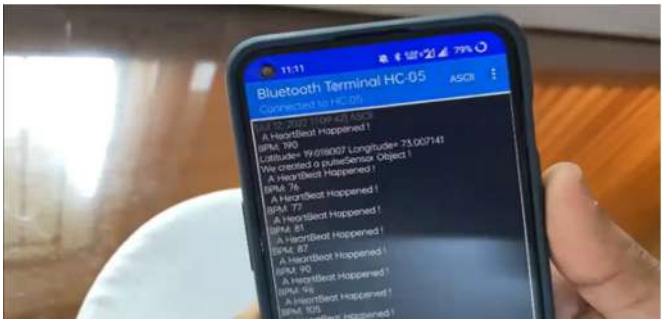
```
#include<TinyGPS++.h>
#include<SoftwareSerial.h>
#define USE_ARDUINO_INTERRUPTS true    // Set-up low-level interrupts for most acurate BPM math.
#include<PulseSensorPlayground.h>     // Includes the PulseSensorPlayground Library.

static const int RXPin = 4, TXPin = 3;
static const uint32_t GPSBaud = 9600;

// The TinyGPS++ object
TinyGPSPlus gps;

// The serial connection to the GPS device
SoftwareSerial GPS(RXPin, TXPin);

// Variables

const int PulseWire = 0;       // PulseSensor PURPLE WIRE connected to ANALOG PIN 0
const int LED13 = 13;          // The on-board Arduino LED, close to PIN 13.
int Threshold = 550;           // Determine which Signal to "count as a beat" and which to ignore.
                               // Use the "Getting Started Project" to fine-tune Threshold Value beyond
default setting.
                               // Otherwise leave the default "550" value.

PulseSensorPlayground pulseSensor;  // Creates an instance of the PulseSensorPlayground object called
"pulseSensor"


void setup(){
  Serial.begin(9600);
  GPS.begin(GPSBaud);
}

void loop(){
  {
}
  while (GPS.available() >0){
    gps.encode(GPS.read());
    if (gps.location.isUpdated()){
      Serial.print("Latitude= ");
      Serial.print(gps.location.lat(), 6);
      Serial.print(" Longitude= ");
      Serial.println(gps.location.lng(), 6);

       Serial.begin(9600);          // For Serial Monitor

  // Configure the PulseSensor object, by assigning our variables to it.
  pulseSensor.analogInput(PulseWire);
```

```
pulseSensor.blinkOnPulse(LED13);       //auto-magically blink Arduino's LED with heartbeat.
  pulseSensor.setThreshold(Threshold);

  // Double-check the "pulseSensor" object was created and "began" seeing a signal.
   if (pulseSensor.begin()) {
    Serial.println("We created a pulseSensor Object !");  //This prints one time at Arduino power-up,  or on
Arduino reset.
  }
    }
    }

 int myBPM = pulseSensor.getBeatsPerMinute();  // Calls function on our pulseSensor object that returns BPM as
an "int".
                                               // "myBPM" hold this BPM value now.

if (pulseSensor.sawStartOfBeat()) {            // Constantly test to see if "a beat happened".
 Serial.println("  A HeartBeat Happened ! "); // If test is "true", print a message "a heartbeat happened".
 Serial.print("BPM: ");                        // Print phrase "BPM: "
 Serial.println(myBPM);                        // Print the value inside of myBPM.
}

}
```

5.2. *Working illustrations of the helmet.*

Following image, Figure 6, depicts the data after wearing the smart helmet. First the location of the institute (IMU-NMC) at Navi Mumbai i..e latitude of 19.018^o N and longitude of 73.007^o E. Moreover data also shows beats per minutes (BPM) with the help of pulse sensor connected to the arduino uno. This image confirms the GPS location of the crew, his physical condition etc. Accelerometer shows the depth of the person inside the water in case of man-overboard condition arises along with his exact location with GPS coordinates.

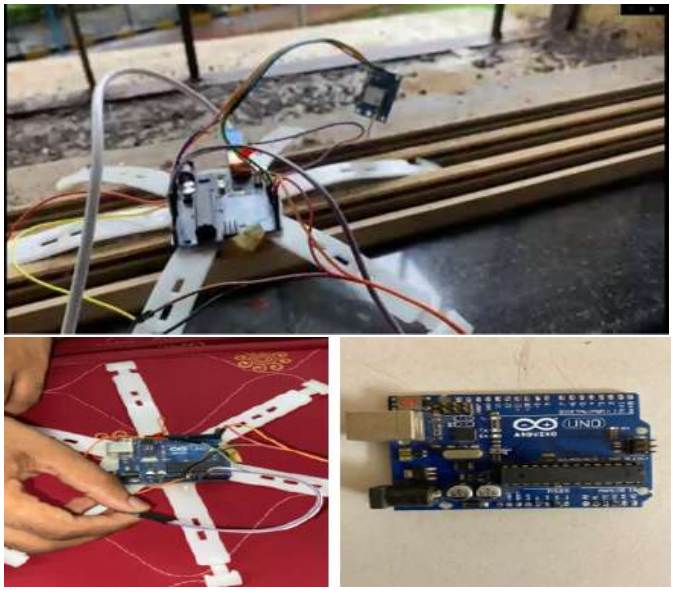
Figure 6: Output via Bluetooth in Smart Phone.



Source: Authors.

Following images shows the internal harness of safety helmet and arrangements of components with battery.

Figure 7: Authors prototype of design and Arduino Uno board.



Source: Authors.

References.

[1] Arduino Uno store, Arduino c.c., ATmega328P microcontroller.

[2] Abd Elkhalik Kamal and Eldin Soliman Selmy, “The need of man overboard (MOB) detecting and tracking-system descriptive analysis.” The 9^{th} China International Rescue and Salvage conference, Ningbo, September 2016.

[3] Debashis Das, “How does the Pulse sensor works and how to interface it with Arduino”, Circuit Digest, 2022.

[4] Fisayo V Akindehim et. Al. “Effectiveness of seafarers safety measures on board vessel”, Asia- Pacific journal of Maritime education, Vo.1(2), June 2015.

[5] Flyrobo blog. The Architecture of Arduina Uno.

[6] Harshil Patel, ?How does MQ-3 Alcohol Detector Work with Arduino and detect Alcohol?, Circuit digest, 2022.

[7] Iksiroh El Husan et.al. “Effectiveness of the use of personal protective equipment (PPE) by cadet on board”. Advances in Engineering Research, Atlantis press, Vol. 186, 2019.

[8] ILO code of practice. “Safety and health in ship buildings and ship repair” revised edition, 2019.

[9] Ming Liang Zhong and Fei Meng, “A YOLOv3 based non-helmet use detection for seafarers safety a board Merchant Ships”, J. of Physics conference series, Vo.1325, Oc. 2019.

[10] Mohit, Marine Insight, Measures Taken During Shipboard Operation for the Safety of Ship?s Crew, Cargo and Marine Environment, 2019.

[11] Microcontroller lab, Interface NEO-6MV2 GPS module with Arduino.

[12] SHM ShipCare, How to take care of personal safety on ships?, 2018

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 110–118

ISSN: 1697-4840, www.jmr.unican.es

Corsairs'activity and contracts

Isabella Lambert[1,*]

ARTICLE INFO

Article history:
Received 22 May 2023;
in revised from 28 Jun 2023;
accepted 03 Sep 2023.

Keywords:
Captives during the Modern Era, ransoming, contract, legal procedure, signature, freedom, Christendom, Mercedarians, Trinitarians, maritime law, oath, verbal agreement, written agreement, women ransoming, Libyan archives, Moroccan Archives, Tunisian Archives, Italian Archives, French archives, Diplomacy, Consulates, Ottoman empire, French royalty, international relations.

ABSTRACT

The redemption of captives in Barbary occupied a considerable place in the diplomatic relations between the Barbary and Christian powers in France during the modern period. Many actors, it is true, intervened to varying degrees. The best known were the religious orders, specializing in the redemption of captives, mainly in the Middle Ages, the Trinitarians and the Mercedarians, acting on the scale of Christendom, but also more local orders in Spain, France, or Italy. Similarly, we note that civil, secular people played a major role as intermediaries in these transactions, not only for commercial purposes, transforming the buyback operations into real commercial transactions, using the probative force of the signing of contracts to obtain their execution as if they were trading in goods.

Merchants were subrogated by families of captives. They were used to charter ships, trade, barter or smuggle men and goods. Finally, to help the poorest being the object of land raids, sailors forming part of the crews, or merchants kidnapped with their cargoes, the municipalities could carry out redemptions, collective or individual, by resorting to notaries in France. On the other side of the Mediterraneean, private agreements were taking place between customs intermediaries, traders, consuls, and Ottoman authorities in the Regencies.

In all cases, the terms of the negotiation, fixing of the price, payment of taxes and commissions to the intermediaries followed purely commercial logics, with a sometimes vague or extremely standardized legal framework, depending on whether one was within the framework of the application of peace treaties, respect for "capitulations", or private agreements between traders, contracts signed before a notary. But sometimes also, words or verbal oaths were exchanged only according to one's religion, within the framework of "rescatti" contracts.

Finally, some captives escaped any normative rule and any writing. They could either be released immediately on the boat which was to bring them back into captivity in Barbary, thanks to the process of the "Alafia" and the payment of a verbally agreed ransom, or fled, sometimes by returning to France and escaping the trials of the Inquisition, thus diverting attention from a momentary Muslim conversion that they forgot as soon as they reached their country.

1. Introduction.

The stakes in the western Mediterranean from the twelfth century to eighteenth century were less the struggle between Christianity and Islam than internal rivalries specific to each of these spaces. The French crown was too busy protecting its borders against Spain or England, or restoring its finances, to embark on an expansionist policy in the Maghreb. She needed to keep the peace in that sector of the Mediterranean. Similarly, Spain or the Italian republics had always sought to privilege commercial relations over war with the Ottoman countries[2].

The Maghreb powers, preoccupied with their internal economic and social problems, considered the question of piracy and the ransom of captives as an obstacle to the maintenance of peace. This was to prevent problems from escalating into

[1]La Rochelle Universit, France.
[*]Corresponding author: Isabella Lambert. E-mail Address: ilcinearts@gmail.com.

[2] V. Lagardère, Histoire et société en Occident musulman au Moyen Âge : analyse du Mi'yār d'al-Wanšarîsî, (Madrid, 1995).

a breach of the truce. The principle, affirmed from the first treaties, was that any captive had to be handed over without financial compensation, therefore without ransom[3]. For this, the captive had to be a subject of one of the sovereign signatories of the peace, the pirate also, and finally his capture had to be made after the signature and the ratification of the treaty.

Diplomatic correspondence, however, testifies to the frequency of disputes relating to the origin of the captives[4]. In times of peace, the ransom was certainly not required, but the fear of reprisals or a breach of the peace could lead, punctually, to its settlement. In this sense, one could consider that these ransoms, not provided for by the treaties and not obligatory, were a means of avoiding a breach of this peace and a return to a state of war. They could be seen as a pragmatic mode of conflict regulation.

Only captives taken outside the truce period were therefore subject to a ransom demand[5]. If the state of war persisted, then only the laws of the market prevailed, which did not necessarily exclude diplomatic or even military pressure. Basically, the captive had to negotiate with his master a redemption price and collect, one way or another, the agreed sum. If the truce was signed, then the calculation and settlement of the ransom were more strictly framed and codified in writing. They called for long and difficult negotiations, because the main obstacle to the enactment of peace was the settlement of the question of the captives, as the important diplomatic correspondence of the time shows.

The negotiators distinguished two types of captives, which did not bind the State in the same way: either those held by the sovereigns themselves – their number was sometimes considerable; or those that were privately owned. In the first case, the political dimension meant that the captives constituted a lever of pressure for whoever held them[6]. But, insofar as the captives were on both banks, the interest was to exchange them. The sultan did not always want to free his captives first[7]. He then had to deposit in Paris a guarantee in money which acted as surety. This would be lost if, within a period fixed by the treaty, the Muslim captives had been freed and the Christians still remained captive. Conversely, the King of France had to put a sum of money on bail while the exchange took place.

2. A private captivity.

For those detained by private individuals, the settlement seemed more complex. When their number was too great, or when the resources of the Treasury were insufficient, it was left to each captive to redeem himself by his own means. But, unlike the conditions provided for in the peace treaties, these redemptions were framed by rules, which aimed to guarantee the interests of the captive, without harming those of the owners. It could then happen that the captives sought outside help, that coming from religious or political institutions, from their families or from merchants, consuls, and their intermediaries.

To read the notarized contracts kept in the archives and instrumented in these ports, French merchants arrived in Muslim ports only to do business with other French, and this included signing contracts for the redemption of captives. However, the presence of written documents signed by Arab traders in the municipal archives of the city of Tripoli invalidates this impression of compartmentalization between the various communities that the historian Dominique Valérian gave when reading the French archives[8].

The apparent partitioning between the various communities and the weakness of the contacts with the local actors of the trade was caused, in modern times, in the port cities of the Barbary powers, by the existence of "fondouks", buildings fitted out to shelter consuls and merchants, most often for the time of their journey. They could thus exercise their trade peacefully, whether for the trading of goods or for, and this is the subject that interests us, the redemption of French captives[9].

The use of writing and specialized intermediaries, in particular the dragomans and brokers often established in the ports of Barbary, made it possible to limit direct relations with the local environment as much as possible. But it was not obligatory and remained little justified, in the case of the French merchants residing in the ports for long months. In addition, most redemption transactions were cash sales. In this case, they did not necessarily require the writing of a document or the signing of a contract. Rather, they were based on the word given during a transaction[10].

It is true that business relations between Christian and Muslim merchants were not always limited to simple transactions[11]. They sometimes required the drafting of a contract before a notary. This recourse to the probative value of writing, that ap-

[3] Archives Générales de Simancas, Série K, 1533B36, Correspondance de Charles IX à Philippe II pour la libération de Turcs retenus à Rome (pour échange).

[4] Frère Cerone, (affaire concernant Tunis), Alfonse le Magnanime et Abu Omar Othman, traités et négociations pendant le règne de Sicile d'ici et de là, du phare du règne de Tunisi, (« Alfonso il Magnanimo ed Abu 'Omar Othmân, Trattative e negoziati tra il Regno di Sicilia di qua e di là dal Faro ed il Regno di Tunisi, 1432-1457 »), A[rchivio] S[torico] S[icilia] O[rientale], (1912).

[5] D. Valérian, Le facteur économique dans la politique catalane à Bougie (XIIIe-XVe siècle) et M.T Ferrer et D. Coulon, L'expansion catalane en Méditerranée au Moyen-Age, (« L'Expansió catalana a la Mediterrània a la baixa edat mitjana »), (Barcelone, 1999).

[6] Guillaume Calafat, Les interprètes de la diplomatie en Méditerranée. Traiter à Alger (1670-1680), dans J. Dakhlia, W. Kaiser (dir.) : « Les Musulmans dans l'histoire de l'Europe. II. Passages et contacts en Méditerranée », (Paris, 2013).

[7] Abdallah al-Targuman, Frere Anselmo Turmeda, La Tufa, autobiographie et polémique islamique contre le christianisme (« Autobiografía y polémica islámica contra el Cristianismo » de 'Abdall āh al-Tarğumān, Fray Anselmo Turmeda), trans. de Elpaza), (Rome, 1971).

[8] D. Valérian, Les archives de Marseille, sources de l'histoire du Maghreb médiéval : le cas du port de Bougie (XIIIe -XVe siècle), Annales du Midi 2001, nr 113, 5-26. Et Le fondouk, instrument du contrôle sultanien sur les marchands étrangers dans les ports musulmans (XIIe -XVe siècle), in C. Moatti (dir.), « La mobilité des personnes en Méditerranée, de l'Antiquité à l'époque moderne, procédures de contrôle et documents d'identification », (École française de Rome, 2004).

[9] J. Revault, Le fondouk des français et les consuls de France à Tunis, (Paris, 1984) et J. Revault, La grande synagogue de Tunis, (Cahiers de Tunisie, Nr 41).

[10] W. Kaiser, Échanges non coopératifs en Méditerranée. Les rachats de captifs aux XVIe -XVIIe siècles, in : S. BOUBAKER et A. ZYSBERG (éd.), « Contraintes et libertés dans les sociétés méditerranéennes aux époques modernes et contemporaines, XVIe-XVIIe siècles, Tunis et Caen », (FSHSU Caen/CRHQ/CNRS, 2007).

[11] G. Calafat, Les juridictions du consul : une institution au service des marchands et du commerce, (École Française de Rome, 2017).

peared above all in French port cities such as Marseille, Narbonne, Arles or Montpellier, could pose a problem, in an intercultural context bringing together merchants of different religion, language, and origins, rules and practices in matters of commercial law, if not opposed, at least dissimilar.

Hence the question of the need for writing between Muslims and Christians, to regulate relations with the "dhimmis," that is to say with any citizen of a Muslim State who was not of this faith[12]. In principle, such associations were prohibited, because they implied a formal equality between contractors, which would have challenged social and political hierarchies[13]. It should be noted that French merchants were also subject to specific taxes, especially customs, even in the case of the redemption of captives. In practice, and for the redemption of French captives, the legal rules concerned the "dhimmis" and often served as a reference for regulating relations with Latin merchants, even if they did not work mechanically[14].

Moreover, this lack of official regulation applied, except in cases of piracy, for which the provisions of the Capitulations or the peace treaty signed by the Muslim sovereign with the royalty of the country came into force. In any case, this is what Gabriella Airaldi affirms, in her collection "Genoese in the Islamic world. »

Similarly, on the other hand, the papacy, faced with the number of commercial associations between Christians and Muslims in France, did not see them with a lenient eye. But how to control relationships across borders that were not limited to simple sales operations? Thus, in 1347, the Genoese notary of Bougie reported several claims owed by Muslims.

It should not be forgotten that Muslims only exceptionally went to Christian ports. They therefore rarely had the opportunity to appear in the meticulousness of notaries. As for the contracts made in the Muslim ports, they have only rarely been preserved, most being contracts drawn up by French notaries that can be found in the archives of Mediterranean cities.

Thus, according to the municipal archives of Libya, the agreements between Christians and Muslims were more numerous than what we can see today from the documentation preserved in Europe. The fact remains that such contracts raise questions for us: about the authority in place to register them, the forms required, the mandatory information, the necessary witnesses, and the probative value of the act[15]. The phrase "under penalty of double," so common in Latin documents, was never found in Arab or Judeo-Arab contracts. For example, the 1422 treaty between Florence and the Mamluks only specified that sales had to be made before notaries ('udül) and according to the law (Sharï'a). The contracts instrumented by the Latin notaries did not differ in their form from the other acts present in the clerks' minutes and therefore followed the rules in use in the Christian powers.

In other cases, all the witnesses could be Christians[16]. This was not a rule always followed, and everything indicated relatively flexible practices. But, when the contracting parties took the oath, they did so according to a form specific to each one. In modern times in Tunis: "Following an ancient practice, an oath by each of the signatories on his own religion could be used to sanction legal acts. The Beys of Tunis recognized Christian and Jewish oaths as judicial evidence[17]."

In general, any contract had probative value when it complied with the law of the notary who had signed it. The treaties that laid down the need to respect notarial contracts never specified that these had to be subject to double validation by both Muslim and Christian authorities. The question of language also posed other difficulties, because the document had to be readable and understood by everyone. If necessary, the use of dragomans made it possible to provide immediate oral translation.

It also appears, in certain contracts, that French captives had the right to appoint special or general prosecutors, depending on the terms used in the contracts, to assert on their behalf their rights to their property located far from them. The appointment of this attorney for the management of land, often in inheritance cases, in the country of origin, was common and required the use of writing[18]. This was the case, for example, of Pierre Troulecty, a slave of the Bey, who elected as Attorney General Madeleine Couronna, living in Venice, "so that in his name she could withdraw everything that the late Joane Haura had left him during his death and to do all that is appropriate in this regard as if the said settlor were present and in the event of refusal on the part of the heirs of the said Joane Haura to compel them by way of justice[19]. »

Also, for Frédéric Hitzel:

"[. . .] the condition of the slave in the Ottoman world was much better than that of the Greek or Roman slave, because of Koranic precepts. A master, for example, owed his slave medical care, proper food, and maintenance in his old age. If a master failed in his obligations, the judge or kâdî could oblige him to fulfill them, or push him to sell or free him. Likewise, a master should not overload his slave with work and, if he did so out of cruelty, he would be liable to punishment."[20]. »

[12] J. Ulbert, La fonction consulaire à l'époque moderne : définition, état des connaissances et perspectives de recherche dans J.Ulbert et G.Le Bouëdec, (dir), « La fonction consulaire à l'époque moderne, l'affirmation d'une institution économique et politique (1500-1700) », (Paris, 2006).

[13] P. Grandchamp, Une mission délicate au XVIIe siècle en Barbarie, J.B Salvago, drogman vénitien à Alger et à Tunis, 1625, Revue Tunisienne, nr 30, (Paris, 1937).

[14] M. Fontenay, Pour une géographie de l'esclavage méditerranéen aux Temps modernes, Cahiers de la méditerranée, 65, (Paris, 2002), URL [http://cdlm.revues.org/index42.html]

[15] M. TALBI, Les courtiers en vêtements en Ifriqiya au IXe-Xe siècle, d'après les Masa'ilal-Samasira d'al-Ibyani, Journal of the Economic and Social History of the Orient, (Tunis, 1962).

[16] D. Valérian, Ports et réseaux, op.cit., 77.

[17] A. Udovitch, Aux origines de la "commanda" dans l'ouest, Islam, Israel, Byzance, ("At the origins of the western Commenda, Islam, Israel, Byzantium"), The University of Chicago Press Journal, (Chicago, 1962).

[18] D. Valérian, Ports et réseaux d'échanges dans le Maghreb médiéval, Bibliothèque de la Casa de Velázquez, 77, (Madrid 2019).

[19] Sebou Alsnian, "Commenda and the family firm in Julfan Society", (2007), [https://brill.com/view/journals/jesh/50/2-3/article-p124_3.xml?language=en] et J-C Zeltner, Tripoli, carrefour de l'Europe et des pays du Tchad, 1500-1798, (Tripoli, 1997).

[20] F. Hitzel, L'Empire Ottoman, XVe- XVIIIe siècle, (Paris, 2002) et J. Heers, Les Négriers en terre d'Islam, (Paris, 2003).

3. The different categories of captives.

The very ambiguity of the French captives 'status, appeared in the French, Algerian and Tunisian archives of the 17th century and made any attempt at legally valid accounting more difficult. Nevertheless, Laurent Charles Féraud mentioned, in 1671, a count of Christian captives[21]:

"Osman-Bey wanted to give himself the satisfaction of seeing parade before him, as an army general would have done, all the Christian slaves captured by his corsairs. On this occasion, his generosity went so far as to gratify each of these almost naked unfortunates with a bonnet, a camisole of bad cloth, a piece of linen to make shirt and underpants. The number of captives held in these prisons was listed by one of these unfortunate "slaves": slaves from the old prison: 490, slaves from the new prison: 474, slaves from the new prison: 475, slaves from the castle and private houses: 120, forming a total of 1,559 captives, including six religious[22]. »

However, in 1685, the military intervention of Estrées allowed the release of one thousand two hundred slaves. In the meantime, the Tripolitan corsairs made numerous raids on sea and on land, as evidenced by the construction of new prisons. But the system where slaves released voluntarily or forcibly had to be replaced remained, hence the need for new catches. Nevertheless, it seems that the number of Christian slaves in Tripoli did not exceed two thousand souls[23].

The redemption contracts from the Montpellier archives tell us that educated captives could sign their redemption acts themselves[24]. This represented 23% of the captives, against 77% of the illiterate. It should be noted that the social origin of the captives was not indicated in the repurchase contracts, but, given the high percentage of illiterates unable to sign, one guessed their extraction. Most "had previously been peasants, fishermen, ordinary soldiers or simple sailors unable to write or sign – officers and masters were enlisted as crew members rather than rowers." (1644).

In the various documents consulted at the time, between November 1593 and August 1594 for example, there were 28 taken and 1 722 captives held in the prisons of Algiers. Between 1628 and 1634, the Algiers took 80 merchant ships from France, for a total of 986 captives. Between 1628 and 1641, they took 131 ships and three-masters from the English, totaling 2 555 subjects' prisoners of his Majesty. As for the pirates of Tripoli, although among the least active in slavery, they succeeded in bringing back 75 Christian ships and 1085 captives between 1677 and 1685[25].

Ellen Friedman[26], from a corpus of 4 500 captives, shows how more than 90% of them remained in Barbaria for less than ten years, only 5% between 11 and 20 years old and approximately 2% more than 20 years[27].

At the same time, the three regencies of Barbary, who thought only of freeing themselves from the yoke of Constantinople, advocated independence[28]. This did not facilitate the task of the Sultans of the Porte[29] who wished to honor their promises made to the King of France.

Tunis was the last city in North Africa to remain under Ottoman rule. She was the first to get rid of her pasha, at the end of the 16th century. The region was then governed by a dey, before a former slave founded, in 1613, a dynasty of beys or former army officers, and this until 1705. In Tripoli, annexed in 1551, the pashas became simple masters of ceremonies in 1603. Then, it was a succession of deys who came to power, chosen from among the janissaries or the Ra'is.

And during almost all the 17th century, Algiers was governed by pashas appointed for three years by Constantinople. The interior provinces were governed by the Beys and a divan, a council composed of Ottoman soldiers or janissaries, shared power with the tai'fa, the assembly of ra'is. In 1659, the Pasha lost all his powers during a revolution and an Agha (military commander), then, from 1671, an elected dey reigned. But of the eleven elected, ten were assassinated. It was only after 1750 that power stabilized[30].

In March 1619, France began to sign a first agreement with Algeria for the raids to cease and all French captives to be freed. But this agreement, and those that followed in the history of relations between France and Barbary, were short-lived. Most were given little respect. In March 1620, a Provençal polacre had been boarded, its goods requisitioned and the entire crew decapitated[31]. The Algerian Embassy in Marseilles was soon

[21] L-C Feraud, Annales Tripolitaines 1852-1888 et Histoire des villes de la province de Constantine, Bougie, Gigelli, Sétif, Borj bou Arridj, Mesila, Boussada, Philippeville, Alger et Constantine, 1869-1876, 4 volumes, volume 2.

[22] F. Hitzel, L'Empire Ottoman, XVe- XVIIIe siècle, (Paris, 2002) et J. Heers, Les Négriers en terre d'Islam, (Paris, 2003).

[23] C. Windler, Diplomatie et interculturalité : les consuls français à Tunis, 1700-1840, (« La Méditerranée : politique, négoce et culture »), Revue d'histoire moderne et contemporaine, (2003), et L. de Mas Latrie, Traités…, op.cit.

[24] Archives Départementales Hérault, (Archives Départementales de Montpellier, Juridiction consulaire 8 B : Jugement et sentences rendus d'autorité par l'Intendant de Languedoc et des officiers de l'Amirauté, matières de contrebande et de commerce prohibé, et listes du clergé régulier (787-1794)

[25] L. Menouche, La course et ses conjonctures, 1700-1764, recherches sur l'Algérie à l'époque ottomane :[https://www.cairn.info/recherches-sur-l-algerie-a-l-epoque-ottomane-ii–9782912946959-page-5.htm?contenu=resume#]

[26] E. Friedman, Captifs chrétiens soumis à un dur labeur en Alger, XVIe-XVIIIe siècle ("Christian Captives at "hard labor" in Algiers", 16th-18th centuries"), The International Journal of African Historical Studies (1980).

[27] Archives en ligne, Liste des captifs chrétiens rachetés par les Mercédaires à Alger (1644) ; Rachat de dix-sept esclaves en la ville de Tunis par le commandeur du couvent de Marseille (1666), État des esclaves de la ville d'Agde qui sont en Barbarie (1670), Rachat de nombreux captifs en la ville de Salé (1674), Rachat de quarante-six esclaves en la ville de Meknès (1690), Relation succincte de plusieurs aventures arrivées dans le cours de la rédemption des captifs ... de 1704 à 1712 et 1644-1774 : [https://www.archiveenligne.fr/2022/10/02/liste-de-captifs-francais]

[28] A. Molho, D. Curto, Les réseaux marchands à l'époque moderne, Annales HSS, 58, (2003).

[29] The « door » or « Gorgeous door » was the central government of the Ottoman Empire.

[30] C. Moatti, (dir.), La Mobilité des personnes en Méditerranée de l'Antiquité à l'époque moderne : procédure de contrôle et documents d'identification, « École française de Rome », (Rome, 2004).

[31] F. Charles-Roux, France et Afrique du Nord avant 1830, Capture et relâche de Mas de Castellane avec une centaine d'hommes partis de la négociation pour le traité conclus en 1619 mais capture de 200 nouveaux marins français entre 1619 et 1620, Collection du Centenaire de l'Algérie, Revue « Archéologie et Histoire », (Paris, 1932).

surrounded and the besieged arrested or killed[32].

Despite the agreements concluded, the raids and captures continued unabated. Thus, the general of the galley Philippe-Emmanuel de Gondi, count of Joigny, launched a fleet of seven ships to seize two Algerian corsair ships and 160 Muslim prisoners[33]. Captives, as we have seen previously, could not be sold without the establishment of a contract written in clear and precise language[34]. The contract, most often in Latin, Italian or French, contained a description of the slave, his age, his country of origin, his sex, his price as well as all the details characterizing him. Many testimonies also attest to the use of these contracts in the Middle Ages in Islamic countries, especially in Andalusia and in the markets of the Arab Middle East.

4. Content of contracts.

The registers of the courts of Justice and the documents archived in Tripoli include many private contracts, where the identity of the seller was carefully mentioned in order to ensure his possessions in captivity[35]. If the buyer or the drafter of the contract had difficulty knowing the identity of the seller, one or the other had to call on a guarantor. It was a measure especially adopted for traders in captives, often non-Muslims, who went to the markets where they sold or bought back captives and slaves. Many documents relating to these guarantees required by those merchants trading on the markets of Fezzan, Benghazi, Tripoli, Egypt and Iraq have thus been kept in Libya[36].

These security requirements would later concern, with the same applicable legal rules, the credit sales of slaves, for a merchant who bought a certain number of captives and paid only after selling them on the markets of the north of the Libya or in the Arab East[37].

From the court records, if there was a breach of the terms of the contract by either party, it could be canceled or reviewed by lowering, for example, the price, when possible. In less than a century, from 1693 to 1783, in the chancellery of Tripoli, nearly three hundred and eighteen redemption contracts were signed and almost as many Christians freed by the Porte. These acts of redemption generally targeted men taken on ships after shipwreck or fire during the race. According to the Nantes archives, the buyout contract could be both individual and collective. In the latter case, a single act could concern two, three or six people, or even larger groups of captives.

Most of the time, the contracts were written in Italian, Latin or French. Indeed, the French consulate having been created in Tunis only from 1577, it represented, until the middle of the 17th century, all the Christians in the regency[38]. Its Chancellery ensured the recognition and recording of acts legally validated, approved and recognized by the other courts of friendly countries. The maritime consulate took care to consolidate the authenticity of the act: it recalled that the contract was drawn up in the chancellery and in the presence of "trustworthy witnesses," this expression serving as proof in the event of a violation of the clauses of the contract[39].

In addition, the precise "date of the contract" was mentioned, not only the year, the month, and the day, but also the time indicated by two expressions: "before noon" or "after noon". This made it possible to have, by a logical classification, the order of the redemption operations, as well as the number of captives redeemed per day, month, and year. A preliminary contract might have been signed beforehand, but it was not systematically mentioned. Sometimes, on the contrary, the final act nevertheless revealed the existence of a promise of redemption between the parents of the captive(s), the mention of a power of attorney or the name of the intermediaries. Finally, it outlined the duration and stages of the negotiations and made it possible to calculate the time interval necessary for the completion of the negotiations[40].

Other mentions were added to the contract: on the one hand, the name of the officer in charge of drawing up the act or his replacement, in the absence of the chancellor; on the other hand, the names of the two witnesses, whose role was to attest to the authenticity of the document, with mention of their surnames and first names, their geographical origins, their professions and residences. Most of the witnesses were French merchants from Tunis or people from the Church representing the Apostolic Prefect of the Mission of Redemption on the spot[41]. Once the deed was drawn up, the redeemed captive had to sign the contract. And, if he could not write, he could just draw a cross. The deed was also signed by the Chancellor and the witnesses.

The chancellor, often a merchant residing in the towns of Algiers, Tunis, Sale, or Tripoli, then recorded the deed in his register, helped by the dragoman for the translation. These contracts were all written in the same way and were structured in three parts: date of establishment by the chancellor or his representative, indication of the identity of the captive, nationality

[32] J. Morgan, Une histoire complète d'Alger ("A complete history of Algiers…"), (Londres, 1731)

[33] B[ibliothèque] N[ationale] de F[rance], NAF 22149-22154, Recueil des pièces relatives à l'histoire ecclésiastique, XVIe-XIXe siècle, NAF 22153 V, Clergé régulier 1403-1771, Pouvoirs donnés par frère Raymond Allard, provincial de l'Ordre de N.-D. de la Merci, aux RR. PP. Michel Auvry et Pierre Recaudon, pour aller racheter les chrétiens captifs à Alger (23 avril 1669).

[34] D. Panzac, ibidem, ROMM, 47.

[35] Ibn 'Abidin, Mohamed, Jurisprudence Islamique XVIIIe siècle, (« Radd al-Muhtar'ala al-Durr al-Mukhtar »), vol.2, (Beyrouth, 2000)

[36] R. Pillorget, Un incident diplomatique franco-turc sous Louis XIII : le massacre d'une Ambassade de la Régence d'Alger, (1974).

[37] J. Pignon, L'œuvre de Pierre Grandchamp, dans : « Études d'histoire tunisienne, XVIIe-XXe siècle », Nr 49-52, Revue de Sciences Humaines, 1965.

[38] Arnaud Bartolomei et al. (Dir.), De l'utilité commerciale des consuls. L'institution consulaire et les marchands dans le monde méditerranéen (XVIIe-XXe siècle), École Française de Rome/Casa de Velasquez, 2018.

[39] M-M. Carof, Correspondance consulaire ; consulats, mémoires et documents (Affaires étrangères BI et BIII), répertoire, Paris, 1982 et (Anonyme, récit) Relation véritable contenant le rachat de plusieurs captifs.... Détenus à rançon à Alger..., (Paris, 1672).

[40] CADN, Registre des délibérations de la Nation Française et des provisions des consuls - carton 454, du 18 décembre 1709 au 10 mai 1749, Minutes de chancellerie et papiers déposés : Exercice de Claude Balp, (24 mai 1690 – 22 janvier 1692), carton 537. Exercice d'Augustin Chaulan (23 janvier 1692 – 26 novembre 1701), cartons 538 à 543. Exercice de Jean-Baptiste Vitalis (décembre 1701-juin 1713), cartons 544 à 559.

[41] S. Bono, « Le Maghreb barbaresque et l'esclavage méditerranéen aux XVIe et XVIIe siècles », Cahiers de Tunisie, 157-158, 1991.

and identity of his master, the function of the latter and sometimes, the reason for the release.

The amount of the redemption was always specified with the accounting detail, the name of the ship and that of the captain who supported the return trip to a Christian port. One of the important elements in any contract was the mention of the "chain of liberators": the mention of all the intermediaries allowing the redemption with the written commitment of the captive to reimburse the sum paid for his redemption within a period approved by the parts[42].

The biggest disbursement was the actual ransom, to be paid to the boss. It corresponded to the value of the captive, estimated in piastres or Venetian sequins, fixed by his master. We know that certain physical characteristics came into play (sex, age, health), but also the social origin of the slave, his supposed fortune, his professional status, and his rank, as well as his talents and his intellectual merits[43].

A set of various taxes and fees, for the benefit of a few institutions, for example benefiting the Tunisian State through its agents, the raïs of the navy, with sometimes the mention "regal for the raïs of the navy", the raïs staff, the "chaoux"[44] and the customs officers. The sum included the establishment of the buy-back contract and a patent. It increased the price of the ransom. Among these "gate fees" of between 33 and 35 piastres, which could reach 60 or 70 piastres, let us note the "franchise card": a levy of 3 to 5 piastres (or a Venetian sequin), paid in exchange for a certificate given to the redeemed attesting to its issuance. The exit passport was also accompanied by a tax paid to the Turkish Divan (13 to 28 piastres) and another tax paid to the Leather Customs (14 piastres). The piastre was a Tunisian currency corresponding to the rial, made up of 52 aspres (nasri)[45].

The chancellor gave a copy of the contract to the captive. From the 1750s, the term "redemption" was replaced by that of "ransom". From then on, a list of costs incurred systematically appeared, these depending on the quality and function of the captive, his situation, and his nationality. If the captive was foreign, translation rights were added. It was also necessary to plan the cost of the return trip leaving for example from Tripoli with accommodation costs (meals and accommodation on the boat)[46].

Finally, the last part of the contract included the clauses which fixed the obligations and guarantees owed by the various contractors. These clauses first fixed the reimbursement procedures which committed the redeemed (in the case of private redemption) and the charitable institutions (in the case of public and charitable redemptions): the currency, the place, the person, and the deadlines granted for reimbursement of the total amount of the redemption, plus the exchange rate[47].

These clauses always specified the place and especially the person to whom the redeemed had to pay the money: it was often the correspondent who ordered the redemption. Finally, in most of the contracts, a repayment period of fifteen to twenty days was fixed by contract. Only a minority of contracts granted a period of thirty days from the return of the redeemed to his country or, in general, to Christendom. The maritime exchange represented, in fact, an insurance against the risk.

Still exceptional in the 17th century, this clause on the repayment period became important in the 18th century[48]. Thus, the correspondent in Christianity or the intermediary residing in Tunis undertook to guarantee all the risks that the redeemed could run from his embarkation until his disembarkation: accidents by fire, shipwreck at sea, as well as the risk of being captured again by corsairs. Only the exception of natural death could be invoked. At the end of the contract, the redeemed undertook to repay their debt, within the time limits granted, by showing their revenues, their present and future property, inheritances, and future successions, which served as a pledge, and they often made the written promise that in case of death, the debt would be paid by their heirs[49].

4.1. The "riscatti" contract.

For most of them, the acts of redemption were written by the "professional redeemers", religious but especially consuls and merchants[50]. These could operate more occasionally, being only "small merchants" (see distinction made above). If Alain Blondy shows that during the period studied by Fernand Braudel, captivity was considered a "heroic fatality" which fell to nobles, soldiers, and sailors, he also affirms that from the moment the corsairs took away from merchant vessels (and no longer only from military vessels), "slavery no longer took on any painful grandeur, but appeared as the assimilation of human beings to merchandise, to drudgery, exchangeable or re-

[42] H. Helal, Une base de données des contrats de rachat des captifs rachetés à Tunis au XVIIIe siècle [Texte intégral], paru dans « Cahiers de la Méditerranée », 87 — 2013 [https://journals.openedition.org/cdlm/7211]

[43] M. Mollat, De la piraterie sauvage à la course réglementée, XIIIe–XIVe siècle, Mélanges de l'École française de Rome, « Moyen Âge–Temps modernes », t. 87, (1975).

[44] The "chaoux" were a body composed of the twelve most powerful Turks and a leader called ba-chaoux or chaoux-bachi or grand provost. They were not allowed to carry weapons. Nevertheless, they could proceed to the arrest of any person refractory to the law.

[45] A[rchives] d[épartementales] du V[ar] – pour la ville de Toulon, E 557-789, 3 E 3588-3594, 3 E 1/1-206, 3 E 2/1-283, 3 E 3/1-251, 3 E 4/1-493, 3 E 5/1-142, 145-212; pour la ville de Saint-Tropez : 3 E 3388-3406, 3 E 24/1-221, 3 E 66/1-176, 3 E 84/170-171, 176, 3 E 86/1-119, 3 E 92/19-211562-1914

[46] G. Poumarède, Les Consuls de la nation française en Levant et en Barbarie aux XVIe et XVIIe siècles, Annuaire Bulletin de la Société de l'Histoire de France, (Paris, 2001).

[47] CADN Nantes, archives consulaires, S/s AC 43.

[48] W. Kaiser, (dir.), Le commerce des captifs : les intermédiaires dans l'échange et le rachat des prisonniers en Méditerranée, XVe-XVIIIe siècle, Collection de l'École française de Rome, (2008).

[49] M.T Boyer-Xambeau, G. Deleplace et L. Gillard, Banquiers et princes, monnaie et crédit dans l'Europe du XVe siècle, (Turin, 1991) et R. Latouche, Les origines de l'économie occidentale, IVe-XIe siècle, (Paris, 1958).

[50] A D H (Montpellier), Archives du clergé régulier (787-1794), 50 H 47-50 (Rachat des captifs, 1638-1774) : rachat des cinquante-huit hommes d'équipage d'un navire pris par les barbaresques d'Alger (1644), liste des captifs chrétiens rachetés par les Mercédaires à Alger (1644), pièces relatives au rachat de nombreux captifs originaires du Languedoc (1644-1774), rachat de dix-sept esclaves en la ville de Tunis par le commandeur du couvent de Marseille (1666), état des esclaves de la ville d'Agde qui sont en Barbarie (1670), rachat de nombreux captifs en la ville de Salé (1674).

deemable livestock[51]."

The evolution of the very essence of corsair activity, the assimilation of human catches to living booty intended to be exchanged for ransom, led to the growth of the practice of buy-back contracts. Two types of acts were used by captives to redeem themselves. They responded to their own organization and use under the name of "riscatti." These acts, very standardized despite the changes of consuls, dealt with the redemption of the captives in their entirety.

Thus, in the departmental archives of the Var, and those of Draguignan, the deeds of registration of Provençal slaves exchanged or bought back in Algiers, established by the sieur Trubert, commissioner general of the Navy, had been written at Maître Gabriel Renoux, notary in Toulon on June 25, 1668. In this contract, a "donor", from the captive's family (or a pious foundation), advanced the money for the redemption or undertook to reimburse it, once the captive had returned to Europe. Then, the "shooter" (usually an Italian merchant) gave the order to start the procedure to his correspondent(s) in Tunisia[52]. The latter then took on the role of "drawn" by advancing the sum on the spot. The process is interesting because it predated that of the bill of exchange, but used the same operation. Finally, the "beneficiary" who had just been redeemed, undertook to repay, after his return to Europe, his ransom to the drawer, plus variable interest depending on the intermediary[53].

It seems that, logically, the captives first notified their family, who contacted recognized intermediaries in Europe and used these money transfer procedures to avoid the displacement of cash sums. For the owners of the captives, the purpose of captivity in Barbary was to obtain the payment of the ransom as quickly as possible[54].

Thus, it was possible to read, at the end of the "riscatti" contracts: "Fire, the sea, the corsairs are risks which can make them slaves again. Except natural death (God forbid), the redeemed captive binds himself with all his present and future property, and binds his heirs and successors to maintain and fulfill all that is in the contract and will be claimed in all the courts of justice, as he has promised and sworn."

Moreover, the corsair code forbade the taking into captivity of a redeemed individual who had in his possession his "franchise card"[55]. In this case, it was generally expected that the intermediaries would have to house and feed the captives until the release procedure was complete and they could return home[56].

4.2. Immediate freedom thanks to «Alafia».

Sometimes the captivity was short-lived as the exchange or ransom was made immediately off the coast of France. In this case, there was no recourse in writing[57]. The use of the "alafia" process shows how relative the weight of writing in the ransom economy could be. Under the same term "captivity," there were actually very different situations, depending on whether the conditions of capture and detention varied: from just a few hours to several decades[58].

Indeed, for Christian captives of high extraction or high price, the rule was that, as far as possible, the corsairs did not take them to Barbary. They anchored their ships off the French or Spanish coasts and conducted their negotiations from their boats. This mediation of the name of "Alafia" remains less known. The traces left by this type of negotiation and release were much more discreet[59]. They differed from the cases of redemption carried out, for example, by the religious orders of which we have the official lists, the detailed description of the missions and the journeys carried out, as well as that of the celebratory ceremonies, with the procession of the captives in the streets of the cities of Paris or Marseille.

The non-drafting of a contract in the event of "alafia" and the release of the prisoner under cover of payment of an immediate deposit would not be quantified to date. They were mainly archived on the Mediterranean coasts, on the Spanish, Portuguese, and Marseille sides, where the person captured immediately called on the savings and funds held by all the members of his family, even sometimes the crew, neighbors, or commercial relations.

If the ransom could not be paid on board and the crew could not, for example, settle it, the group then joined the ports of Barbary to be put with the captured men into captivity. This sharing of prizes was dependent on the generosity of the captain-privateer, but above all the Bey. Nevertheless, custom dictated that the corsairs received half the value of the catches. The hostages were presented to the Bey who kept the best elements. If no means had been found to pay the ransom, the captives would be staying in prisons or would take the road to the slave markets[60].

5. The escape with the help of "metadores".

At the end of the 17th century, people began to envisage a new way of alleviating the sufferings of captives and increasing the number of those released. It was therefore appropriate to give credit to this new possibility. It was on his return from

[51] A. Blondy, « Les Hospitaliers de Jérusalem », Rhodes et Malte [Texte intégral], Cahiers de la Méditerranée, 97/2 — 2018

[52] A.D du Var, 1B401-441, 3E4/103, fº 774, et Œuvres de rédemption des captifs à Toulon, Gustave Lambert, (Toulon, 1882), BIB 40075, Bulletin Historique et Philologique, (Paris,1906).

[53] R. Guemara, Réflexions sur la course en Tunisie à l'arrivée des Ottomans lors de l'expédition de Lord Exmouth (« Riflessioni sulla corsa a Tunisi dall'arrivo degli Ottomani alla spedizione di Lord Exmouth »), in « Corsaires, esclaves, libérés entre la Ligurie et l'Afrique du Nord au XVI et XVIIe siècle (''Corsari, schiavi, riscatti tra Liguria e Nord Africa nei secoli XVI e XVII"), Convegno di Ceriale, 2004, (Ceriale, 2005).

[54] A D H (Montpellier), Séries C, H, L, 39M, Rachat de dix-sept esclaves en la ville de Tunis par le commandeur du couvent de Marseille (1666).

[55] H. Helal, Une base de données. . . , ibidem, 87, 2013

[56] A. Abidi, Le processus de rachat des captifs dans la Régence de Tripoli de Barbarie au XVIIIe siècle, [https://journals.openedition.org/abpo/508]

[57] S. Bono, ibidem, p. 203 et G.Calafat, La juridiction des consuls français en Méditerranée, Livourne et Tunis au XVIIe siècle : litiges marchands, arbitrages et circulations des procès (2017).

[58] Archiu historic de la pabordia de Santa Maria d'Eivissa, Formentera, 4.028,1, 18 avril 1708, AHPSME, 4018, 43 (s/d), AG OSLE Cyrua criminal, « Proceso de contrabando sobre la sera de Argel (1703) », Archivo Historico Nacional, Registres des archives de l'Alhambra, mars et avril 1552, AHPA, Prot.65, fol 246.

[59] AGS, Leg. 18-65, Avril 1552 et AHPA, Prot.65, fº 246.

[60] R.C. Davis, Esclaves chrétiens. . . , op.cit., p. 147

his third redemption in Morocco (1712) that Moroccan subjects contacted Father Busnot to offer their services[61].

To leave the Moroccan territory at the time, it was imperative to obtain authorization from the sultan in person, authorization which served as a passport. Obtaining this document was subject to the exposure of a valid reason for absence from the territory and its validity was only for a few months. Failure to respect the validity period exposed the beneficiary to severe penalties, which could go as far as physical elimination. It was also possible that certain wealthy families, who had one of their captives in Morocco, entrusted a Christian merchant residing in one of the country's ports with a sum of money sufficient to negotiate the release of the unfortunate prisoner. It turned out that some merchants had failed in the missions entrusted to them and had embezzled the sums received. It would then seem, without being able to support this with convincing facts, that individuals who wanted the rapid release of a loved one in captivity then turned away from the merchants in favor of these "metadores".

The redeemers gave their adhesion to the proposal of the guides without asking any questions. Provided with letters of recommendation, and on their way to Madrid, the "metadores" seemed to be known in Cadiz and circulated freely. The French Trinitarian Fathers, since Father Dan, knew the region well, both on the Spanish and the Maghreb side, and otherwise did not lightly commit the money painfully amassed in France through alms[62]. To keep it safe, they always took care to deposit it at the French consulate in Cadiz or to entrust it to the owners of known trading houses.

The organization of redemptions by the redeeming fathers was carefully prepared. It all started long before the crossing: a role drawn up by the religious order specified which captives were to be ransomed. Sometimes families presented themselves spontaneously to the redeeming fathers to ask them to redeem one of their own[63]. Once the number and the identity of the captives had been defined, the redemptive fathers had to obtain the obligatory agreements when they left France[64]. Only the king could provide them with the necessary diplomatic documents, as well as the right to take with them the goods and sums useful for exchanges or redemptions. As soon as they entered the foreign country, the consul in place ensured their protection by lodging them. Before their departure, the money was exchanged for the only coins usable in Barbary, namely Sevillian piastres.

The journeys remained long, often taking several months, sometimes even several years. Once there, the authority of the country issued the fathers a passport to allow them to circulate freely. The work of locating the sought captives, followed the fixing with the owner of the redemption price. The latter could be very variable and depended a lot on how the negotiations were conducted. The age, the work force (age, origin, corpulence, dexterity, promptness), but also the social condition of the captive, were determining factors[65].

In addition, the price of the captive could also vary according to the social rank of the one who sold him. Thus, the prices demanded by the dey were always higher than those set by private individuals. The Sieur de Vento, because of his social rank, for example, experienced difficulties in being redeemed, because an extraordinary ransom - the price of which was not indicated by the monks - had been requested by the Dey of Algiers. Ten years were necessary for him to succeed in being freed from captivity[66].

The precious consular archives of Tunis delivered for example four thousand different prices. It should be noted, in terms of currencies, that the gold shield of Spain was mainly used until 1625. It was in competition with other currencies such as Sicilian ounces, Naples's ducats, Venetian sequins, Tournament books, Sultanas[67]. The Spanish piastre appeared in 1616 and won quantitatively from 1628, to be used systematically from 1635. This mutation could correspond with new monetary exchanges and marked the victory of the silver system over the gold system[68].

In the seventeenth century, the fluctuations varied from one hundred to five hundred piastres for captives of average value. For captives of exceptional quality, the price could reach five thousand piastres, depending on the professional quality or the noble origin of the captive. But each captive was a special case. In the absence of a scale between seller and buyer, professional categories and social categorization nevertheless remained the only point of reference for setting the price. The Nordics (English, Dutch, Germans) were more expensive than the French since the Capitulations had forced the pirates to turn away from the French hold[69].

According to the situation, as for example in 1686, during the siege of Tunis by the troops united by the Beys and the Algerians, the Pasha freed a captain for three hundred piastres, whereas the tariff amounted at that time to more than two thousand piastres[70]. The Tunisian archives make it possible to fix the prices of the captives and to establish a comparison between

[61] Ahmed Farouk, Captifs et captivités en Méditerranée à l'époque moderne, quelques cas d'évasions de captifs chrétiens au Maroc, fin XVIIe-début XVIIIe siècle, selon le père Dominique Busnot, p. 255-264 - https://doi.org/10.4000/cdlm.7262

[62] Op.cit. Père Pierre Dan, Histoire de Barbarie et de ses corsaires. . . , 1637, 2e éd. 1649

[63] A[rchives] de la C[our] de J[ustice] de T[ripoli], Prix des captifs, prix des esclaves et A.G.L, lettre de 1273, dans le corpus de lettres et reçus d'achats et de rachats jusqu'en 1856, A[rchives] G[énérales] de L[ybie], lettre de 1273, dans le corpus de lettres et reçus d'achats et de rachats jusqu'en 1856.

[64] A D H (Montpellier), Séries 50 H 47-50, Rachat des captifs, 1638-1774 : Rachat des cinquante-huit hommes d'équipage d'un navire pris par les barbaresques d'Alger (1644), liste des captifs chrétiens rachetés par les Mercédaires à Alger (1644) et pièces relatives au rachat de nombreux captifs originaires du Languedoc (1644-1774).

[65] A. Blanc, Le livre de comptes de Jacme Olivier, 1899 t. II-A, https://gallica.bnf.fr/ark:/12148/bpt6k55403b.texteImage

[66] J. Mathiex, « Trafic et prix de l'homme en méditerranée aux XVIIe et XVIIIe siècles », Annales « Economie et civilisations », 2, 1954.

[67] M. Hedi Chérif, « Introduction de la piastre espagnole (Ryal) dans la régence de Tunis au début du XVIIe siècle », Cahiers de Tunisie, 61-64, 1958.

[68] R. Latouche, Les origines de l'économie occidentale (IVe-Xie siècle), (Paris, 1958).

[69] J. Hilaire, « Grandeur et servitude de la justice consulaire : la controverse de l'équité », Revue d'Histoire de la justice, 11, 1998.

[70] H. Maurits Van den Boogert, Les Capitulations et le système juridique ottoman au XVIIIe siècle, ("Capitulations and the Ottoman Legal System in the 18th Century)", Studies in Islamic Law and Society, (Leyde-Boston, 2005).

the different places where the captives were bought. Another example, we are interested in the distribution of redemptions in Tunisia, according to the counts of Mohamed Hedi Chérif as follows:

- France 762.
- Islands 934.
- Italian Peninsula 1323.
- Iberian Peninsula 158.

The same archives show a decline in the number of captives ransomed in Tunis at the end of the 17th century, even if Italy continued to pay a large tribute, due to the demographic relief of the Mediterranean world and the difficulties for ransom payments due to the economic crisis that raged from 1680. As for the French captives, diplomatic action and public redemptions explained the fall in redemptions, the number of which fell from 712 to 49 from 1662 to 1700.

Conclusions.

In conclusion, the weight of writing in the negotiation of the ransom of French captives remained key for their release. Nevertheless, in addition to the process of "alafia", very different means were used to negotiate the price of a captive downwards and without a written contract[71]. But it should be noted that all our research and our findings in the archives will never be able to count the exact number of captives who took an oath and obtained a conditional release, or escaped the hands of their masters, fled without recourse to the redeeming monks or to any official takeover. Not to mention those who avoided investigation by the courts of the Inquisition but still returned to their country of origin after temporarily converting to Islam in one of the Regencies to escape harsh treatment.

In general, hiding its origin as well as possible was part of a logic of liberation at a lower cost. Germain Moüette indeed explained, in his account of captivity that, when he was imprisoned by the Moroccans, the latter inspected the hands of all his companions in misfortune, in order to determine their social origin[72]. Those whose hands were not damaged by manual work sold for much more than the others.

[71] L. Rostagno, « Un visage turc » (« I faccio turco »), commentaires par Maurice Aymard, supplément à Orient Moderno, IV, (Paris, 1983) (« Esperienze ed immagini dell'Islam nell'Italia moderna », Supplemento n. 1 a « Oriente Moderno », Studi e materiali sulla conoscenza dell' Oriente in Italia).

[72] G. Moüette, Relation de la captivité du Sr. Mouette dans les royaumes de Fez et de Maroc, où il a demeuré pendant onze ans, chez Jean Cochart, au cinquième pilier de la grand'salle du Palais, au Saint Esprit, 1683, (récit).

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 119–122

ISSN: 1697-4840, www.jmr.unican.es

Full Mission Bridge Simulation: Basis for Skills and Competency Enhancement of BSMT Students

Capt. Sheila B. Monahan-Picpican[1,*]

ARTICLE INFO

Article history:
Received 24 May 2023;
in revised from 24 Aug 2023;
accepted 03 Sep 2023.

Keywords:
Simulation, Enhanced Training, Bachelor of Science in Marine Transportation, Full Mission Bridge.

ABSTRACT

This study was conducted to determine the competency and skills of students in Iloilo State College of Fisheries in term of maneuvering the ship through Simulation on Full Mission Bridge Simulator. This study is using the descriptive analysis to determine the level of competency and skills of the BSMT students using the Full Mission Bridge Simulator through enhancement by familiarization and monitoring. This study was conducted at the Iloilo State College of Fisheries, Tiwi, Barotac Nuevo, Iloilo.

The respondents of this study consisted of the 260 BSMT 3 students. Purposive sampling was used in this study. The data were gathered from January to February through the pre-assessment and post-assessment questionnaires from IMO MC 6.10- Training Program for Instructor and Assessor Conducting Simulator Based Training and Assessment.

In analyzing research data, the mean, meridian and mode averages were employed. The results of the study in the pre assessment in ship's familiarization the overall mean is 3.664 which is more knowledgeable while in the post assessment in monitoring the overall mean is 3.91 which is more achieved. There is no significant difference between the level of competency and skills of the students before using the Full Mission Bridge Simulator during enhancement through familiarization and level of competency and skills before using the Full Mission Bridge Simulator during enhancement through monitoring.

1. Introduction.

The Commission on Higher Education (CHED) issued Circular Memorandum Order (CMO) No. 20, series of 2015 for all Bachelor of Science in Marine Transportation Schools to upgrade the Competence of all Students. Standards governing the use of simulators as amended 2010 states that all Maritime Higher Education Institutions shall comply with the minimum standards and guidelines governing the use of simulators pursuant to Regulation Section A-1/12 and Section B-1/12 of the Seafarers' Training, Certification and Watchkeeping Code.

In 2010, the Conference of Parties to the STCW Convention was held in Manila and Amendments updating the Standards of Competence required of marine deck and engineering officers at the operational level particularly, in light of learning technologies, new training and certification requirements and methodologies, medical fitness standard for seafarers among others, and ultimately for shipping companies to have a safe, secure and efficient shipping operation on cleaner ocean was considered.

Today, simulator training given by maritime schools and academies is part of the basic training of maritime professionals. The importance of Full Mission Bridge Simulator in the Maritime industry is significant in training maritime students to be skillful in maneuvering the ship to develop professional skills through simulator-based training like shiphandling and manipulation / familiarization on the Full Mission Bridge Simulator will help the maritime students in their desire to become a deck officer.

[1]Iloilo State University of Fisheries Science and Technology, Philippines.
[*]Corresponding author: Sheila B. Monahan-Picpican. E-mail Address: picpicansheila22@gmail.com.

2. Statement of the Problem.

This study aimed to determine the skills and competence of the students to maneuver the ship using Full Mission Bridge Simulator.

Specifically, this study sought to answer the following questions:

1. What is the level of competency and skills of students before using Full Mission Bridge Simulator, during enhancement through familiarization of Full Mission Bridge Simulator?
2. What is the level of competency and skills of students during enhancement through monitoring of Full Mission Bridge Simulator?
3. Is there a significant difference in the level of competency and skills of the students before using Full Mission Bridge Simulator, during enhancement through familiarization and monitoring of Full Mission Bridge Simulator?

3. Methodology.

This chapter presents the research design, locale of the study, respondents, sample size, sampling technique, research instrument, data gathering procedure and data analysis procedure.

3.1. Research Design.

This study used the descriptive method of research. Descriptive research is conclusive in nature, as opposed to exploratory. This research gathers quantifiable information that can be used for statistical inference on your target audience through data analysis.

3.2. Locale of the Study.

This study was conducted to BSMT 3- ALPHA to FOXTROT students of Iloilo State College of Fisheries, Tiwi, Barotac Nuevo, Iloilo who were enrolled 2^{nd} semester of academic year 2016-2017.

3.3. Respondents of the Study.

The respondents of the study were the 260 BSMT 3 students of Iloilo State College of Fisheries, Tiwi, Barotac Nuevo, Iloilo, enrolled 2^{nd} semester academic year 2016-2017.

Table 1: Distribution of Respondents.

Course/Year/Section	*No. of Students*	*Total*	*Percentage*
BSMT 3-Alpha	42	42	100%
BSMT 3-Bravo	47	47	100%
BSMT 3-Charlie	42	42	100%
BSMT 3-Delta	47	47	100%
BSMT 3-Echo	42	42	100%
BSMT 3-Foxtrot	40	40	100%
Total	260	260	100%

Source: Author.

3.4. Sample Size.

A total of 260 population of the BSMT - 3 for SY 2016-2017 BSMT-3 taking Seamanship 5 with Descriptive title: Ship Handling and Manuevering, were considered as respondents of the Study.

3.5. Sampling Techniques.

Purposive sampling was used since the study considered all the BSMT-3 enrolled for school year 2016-2017.

3.6. Research Instrument.

In gathering the necessary data to determine the skills and competence to maneuver the ship using Full Mission Bridge Simulator, the researcher conducted practical assessment in the course Seam 5 (Shiphandling and maneuvering).

3.7. Data Gathering Procedures.

The researcher prepared a communication to the Dean of the College of Maritime Studies requesting permission to conduct the study. The date and time for the conduct of the study were stated in the letter.

Upon approval of the request letter, the researcher immediately started the conduct of questionnaire based on the IMO Model Course 6.10- Training Program for Instructor and Assessor Conducting Simulator Based Training and Assessment. The first assessment was given is the ship's familiarization and the second assessment is for monitoring and evaluation of their performance after their actual maneuvering on Full Mission Bridge Simulator. The performance result were recorded, tabulated and interpolated.

3.8. Data Analysis.

The data gathered were subjected to manual statistical test. The statistical tool used was, descriptive statistics.

Level of Competency assessment result was presented using the following:

Scale	*Description*
5 → 5.00 – 4.21	→ Very Much Knowledgeable.
4 → 4.20 – 3.41	→ Much Knowledgeable.
3 → 4.40 – 2.61	→ Knowledgeable.
2 → 2.60 – 1.81	→ Less Knowledgeable.
1 → 1.80 – 1.00	→ Very Less Knowledgeable.

4. Results.

Table 2: The level of competency and skills of the students before using Full Mission Bridge Simulator during assessment through familiarization.

Questions	Mean	Descriptive
1. Know how to operate power on/off	4.32	Very much knowledgeable
2. Know how to switch from manual to auto pilot steering	3.75	More knowledgeable
3. Know how to adjust the dimmer of the gyro compass	3.55	More knowledgeable
4. Know how to use controls	3.59	More knowledgeable
5. Know how to use thruster controls	3.55	More knowledgeable
6. Know how to read the magnetic Compass	3.55	More knowledgeable
7. Know how to use the echo-sounder	3.59	More knowledgeable
8. Know how to use engine telegraph	3.53	More knowledgeable
9. Know how to operate indicators	3.56	More knowledgeable
10. Know how to operate view controls	3.65	More knowledgeable

Source: Author.

Table 3: The level of competency and skills of the students before using Full Mission Bridge Simulator during enhancement through monitoring.

Questions	Mean	Descriptive
1. Did you check and test the bow Thruster prior for departure?	3.998	More achieved
2. Did you cast off mooring lines in ample order?	3.90	More achieved
3. Did you monitor traffic by means of acquiring targets on Radar/ARPA?	3.74	More achieved
4. Did you operate engine telegraph due regards to change of speed?	3.82	More achieved
5. Know how to use thruster controls	3.83	More achieved
6. Did you execute the helm command due regards to maneuver?	3.95	More achieved
7. Did you participate in your group in practical assessment?	4.130	More achieved

Source: Author.

Table 4: t-Test result on the difference in the level of competency and skills of the BSMT 3 students through enhancement and monitoring of the Full Mission Bridge Simulator.

	Mean	Computed t	t-value
Familiarization	3.664	0.75	1.96
Monitoring	3.91	0.68	1.96

No significant difference (P > .05)

Source: Author.

Conclusions

From the findings, the conclusion was formulated:

There is no significant difference between the level of competency and skills of the students before using the Full Mission Bridge Simulator, during enhancement through familiarization and level of competency and skills before using the Full Mission Bridge Simulator during enhancement through monitoring because the students had already a knowledge about the Full Mission Bridge Simulator for their 1st year and 2nd year academic.

Recommendations:

1. Additional purchased of Full Mission Bridge Simulator according to the CMO 20s, 2014. The equivalent of 1:5, 1 simulator to 5 students.
2. The administration must immediately take action for the requisition of the Full Mission Bridge Simulator.
3. Additional instructor that has an IMO Model Course 6.10. Training Program for Instructor and Assessor Conducting Simulator Based Training and Assessment needed for the Full Mission Bridge Simulator.

References.

Journal:

CHED Memorandum Order No. 20, series.2014.

SOLAS Convention - Wikipedia. https://en.wikipedia.org-/wiki/SOLAS_Convention.

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers including 2010 Manila Amendments.

NAVI-TRAINER 5000 (VERSION 5.10) Instructor Manual Transas Marine Ltd May, 2011.

Training Program for Instructor and Assessor Conducting.

Simulator Based Training and Assessment (Assessment / Training Module).

Internet.

Full Mission Bridge Simulator. http://www.marin.nl/web/Facilities-Tools/Simulators/Simulator-Facilities/Full.

STCW 2010 (Manila Amendments). http://www.warsasha-cademy.co.uk/courses/stcw-safety-and-security/stcw.

http://vstepsimulation.com/news/vstep-poseidon-team-bring-maritime-simulator.

Philcamsat (Philippine Center for Advanced Maritime Simulation. https://www.linkedin.com/company/philcamsat.

Goodwin, C. (1994). Professional vision. American Anthropologist, 96(3), 606–633.CrossRefGoogle Scholar.

Goodwin, C. (1995). Seeing in depth. Social Studies of Science, 25(2), 237–274.CrossRefGoogle ScholarGoodwin, C., & Duranti, A. (1992). Rethinking context: An introduction. In A. Duranti & C. Goodwin (Eds.), Rethinking context: Language as an interactive phenomenon. Cambridge: Cambridge University Press.Google Scholar.

Hutchins, E. (1995). Cognition in the wild. Cambridge: MIT Press.Google Scholar.

Hutchins, E., & Klausen, T. (1996). Distributed cognition in an airline cockpit. In D. Middleton & Y. Engeström (Eds.), Communication and cognition at work. Cambridge: Cambridge University Press.Google Scholar.

Rystedt, R., & Sjöblom, B. (2012). Realism, authenticity, and learning in healthcare simulations: Rules of relevance and irrelevance as interactive achievement. *Instructional Science, 40*(5), 785–789.CrossRefGoogle Scholar.

Lindblom,. (2015). Embodied Social Cognition. Cognitive systems monographs (COSMOS). Berlin: Springer International Publishing Switzerland.CrossRefGoogle Scholar.

Maran, N. J., &Glavin, R. (2003). Low-to high-fidelity simulation-continuum of medical education? Medical Education-.doi:10.1046/j.1365-2923.37.sl.9.x.Google Scholar.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 123–132

ISSN: 1697-4840, www.jmr.unican.es

Proposing a Mathematical Dynamic Model to Develop a National Maritime Security Assessment and Build a National Maritime Security Plan

Adriana Ávila-Zúñiga-Nordfjeld[1,*], Marcus Dansarie[2], Hans Liwång[3], Dimitrios Dalaklis[4], Maximo Q. Mejia Jr.[5]

ARTICLE INFO

Article history:
Received 8 Jun 2023;
in revised from 24 Aug 2023;
accepted 03 Sep 2023.

Keywords:
International Ship and Port Facility Security (ISPS) Code, National Maritime Security Plan (NMSP), National Maritime Security Assessment (NMSA), maritime & port security, national security.

ABSTRACT

A proper assessment of maritime security risks at the national level is crucial to a national maritime security plan (NMSP) in order to secure the concerned country's ports, vessels and territorial sea. Thus, the importance of implementing a national maritime security assessment (NMSA) to counter security threats and ensure the continuity of national and international trade. The most important set of international regulations concerning maritime security is the International Ship and Port Facility Security (ISPS) Code, which includes revision, approval and control of compliance of the Port Facility Security Plan (PFSP), which shall be based upon the Port Facility Security Assessment (PFSA). This paper proposes a mathematical dynamic model that calculates in real time the residual risk for the whole country and each of its ports by adapting and expanding the formula and procedures established in the Code, which since it has already been implemented around the world, gives the opportunity to take advantage of this quantitative solution to administrate maritime security risks on a nation-wide basis and create an effective national maritime security plan, which would allow the concerned authorities to improve situational awareness and adapt to security changes through a better planning of human, economic and material resources to deter security threats. The model was tested with the use of five encoded categories as countries, each of them with three ports, which encompassed three port facilities. The results indicate that this methodology is easy to implement and widespread use of that model could strength robustness in national security. .

1. Introduction.

This research effort builds upon a PhD dissertation, which was focused on the subject of "Building a National Maritime Security Policy" (Nordfjeld Avila-Zúñiga, 2018) and a certain number of articles related to this doctoral study strongly associated to maritime and port security.

Despite the increasing number of incidents related to maritime terrorism at sea, piracy and other types of transnational crimes at sea, there is no consensus for a common universal definition of the maritime security concept. Not even the International Maritime Organization (IMO) has provided a clear definition of the term. Some researchers focus on the absence of security threats in the maritime sector, while other authors emphasise the establishment of security measures and the well-functioning of the rule of law to manage risks at sea. Mejia (2007) define maritime security is "the state of being free from

[1]Dr. (Maritime Safety & Security), Associate Senior Lecturer, Swedish Defence University, Department of Systems Science for Defence and Security, Stockholm-Sweden. Adriana.Nordfjeld@fhs.se

[2]PhDc Swedish Defence University, Department of Systems Science for Defence and Security & School of Informatics, University of Skövde, Skövde, Stockholm-Sweden; Marcus.Dansarie@fhs.se.

[3]Dr. Associate Professor, Swedish Defence University, Department of Systems Science for Defence and Security, Stockholm-Sweden, Hans.Liwang@fhs.se.

[4]Dr. (Maritime Safety & Security), Professor, World Maritime University (WMU), Malmö-Sweden, dd@wmu.se.

[5]Dr. Professor, President, World Maritime University (WMU) Malmö-Sweden, op@wmu.se.

[*]Corresponding author: Adriana Ávila-Zúñiga-Nordfjeld. E-mail Address: Adriana.Nordfjeld@fhs.se.

the threat of unlawful acts such as piracy, armed robbery, terrorism or any other form of violence against ships crews, passengers, port facilities, offshore installations and other targets at sea or coastal areas". However, it is worth highlighting that in reality there is not one port in the world that can be declared completely free of security threats. On the positive side, the International Maritime Organisation (IMO) has established a legal and regulatory framework for international cooperation in an effort to make maritime transport of goods and passengers as secure as possible, including the mandatory implementation of risk management instruments through the International Ship and Port Facility Security (ISPS) Code. Yet, the concrete actions for managing risks and deterrence actions must be in accordance with the national maritime security policy for the respective state.

Undoubtedly, to build an effective national maritime security policy (NMSP), the relevant country must establish a national strategy for maritime security first, which must include the development and implementation of a national maritime security plan (NMSP) to support such strategy and the respective threat deterrence actions; restoring passenger and cargo flow, including container cargo, as soon as possible, in the event of an attack or a disruptive event should be a high priority action. However, this plan must be developed based on a national maritime security assessment (NMSA), which must calculate the residual risk related to security threats such as piracy, armed robbery, terrorism, sabotage, illegal transportation of drugs and weapons or any other violent and illegal act against ports, port facilities, ships, crews, passengers, service providers, offshore installations, and other targets in their territorial sea or in the coastal areas.

It is not a coincidence that the United States of America has already developed and implemented a National Plan to Achieve Maritime Domain Awareness (MDA), which includes near-term and long-term objectives, a required program and resource implications, and recommendations for organizational or policy changes, to support the National Strategy for Maritime Security, as directed by National Security Presidential Directive-41/Homeland Security Presidential Directive-13 (Homeland Security of the United Sates, 2022).

Maritime Domain Awareness (MDA), has been defined as "the effective understanding of anything associated with the global maritime domain that could impact the security, safety, economy, or environment (of the United States)" by the Maritime Security Policy Coordinating Committee Of The U.S., (2005). This very same definition has been applied by the Centre of Excellence for Operations in Confined and Shallow Waters from the North Atlantic Treaty Organization, from NATO (2013), to describe the concept of Maritime Situational Awareness. Though Nordfjeld Ávila-Zúñiga, A.; Dalaklis, D.; Mejia Jr, M. Q. & Neri (2021), defined Maritime Security Awareness as "the effective understanding of any aspect related to the maritime domain that can affect the security of ports, ports facilities, its stakeholders and users, ships and its crews; along with the territorial sea and international waters, including the marine environment, as the key element for a proactive and efficient response against maritime security threats". These authors emphasised the importance to distinguish between Maritime Security Awareness (MSA) and Maritime Domain Awareness (MDA). The latter concept is wider and includes aspects related to maritime safety, which are commonly excluded in the maritime security discipline; they also highlighted their concerns about this fusion, which might complicate consciousness of security risks and intensify current lack of knowledge about types of security incidents versus safety accidents or the so called safety near-misses.

In any case, it is crucial to separate maritime safety issues from maritime security in the maritime and port security national strategy and respective plan. Kenneth (2009), correctly pointed out that "the evolution of organized security processes in the maritime sector can be understood as a product of increasing governmental and commercial concerns about the criminal exploitation of seaports, [...] and the rising threat of global terrorism", while Rudner (2009), included maritime ports as part of the "Critical National Infrastructure" and highlighted the need for a national security and strategy plan for the protection of Canada's critical national infrastructure against exogenous risks and threats.

This paper presents a proposal of a mathematical dynamic model that can be used to calculate the residual risk for the whole country and each of its ports regarding maritime security in real time, by adapting and expanding the formula and procedures established in the ISPS Code to develop a national maritime security assessment, which then shall be basis for the respective national maritime security plan, allowing national authorities to improve maritime situational awareness and adapt to security changes through a better planning of human, economic and material resources to deter maritime security threats.

It is structured in the linear form of introduction, followed by a brief explanation of the ISPS Code, including the PFSA and respectively the PFSP, as well as cyber-security and moving next into an explanation of the methodology used and the presentation of the results. Then, the general discussion is presented, along with the associated conclusions and recommendations. Last but not least, future research directions are provided, including theoretical and practical implications for researchers and practitioners in the areas of maritime security.

2. Maritime Security and the ISPS Code.

To enable economic stability and commerce, it is necessary to protect the free flow of goods shipped by sea (Council of the European Union, 2014; MNE 7,2012; Secretary of Defense USA., 2012; Swedish Maritime Administration, 2014; Till, 2009). The shipping system is composed of many autonomous, but interconnected, actors (Swedish Maritime Administration, 2012) ranging from small local ship owners to large international ship operators.

Maritime security is addressed at many levels, from international bodies such as the United Nations (UN) and the International Maritime Organization (IMO) to single ship operators, but also by both military and civilian organizations. These levels and organizations are interconnected and a security decision

made by one will affect the others (Liwång et al., 2015; Swedish Maritime Administration, 2012).

The ISPS Code strictly corresponds to Chapter XI-2 of the International Convention for the Safety of Life at Sea (SOLAS), 1974 [12] [13] which establishes special measures to enhance maritime security. It is "the comprehensive set of measures to enhance the security of ships and port facilities, developed in response to the perceived threats to ships and port facilities in the wake of the 9/11 attacks in the United States", as defined by the IMO (International Maritime Organization, 2012). It is divided in two sections, part A establishes the mandatory provisions, while the non-mandatory ("recommended") part B provides guidelines about how to comply with the obligatory requirements of part A.

Under the ISPS Code, "Contracting Governments may identify a Designated Authority within Government to undertake their security duties relating to port facilities as set out in chapter XI-2 or part A of (the) Code" (International Maritime Organization, 2002b). These maritime security duties and responsibilities include ensuring compliance with the maritime security measures at all ports (where the ISPS Code applies), approval of the Port Security Assessment (PSA) and Port Facility Security Assessment (PFSA), as well as the revision, approval and control of compliance of the Port Security Plan (PSP) and Port Facility Security Plan (PFSP). The PSP/PFSP shall be based upon the PSA and the PFSA, managing all security risk related to the port/port facility and analyses for risk mitigation through the PSA/PFSA, among others (Nordfjeld Ávila-Zúñiga, A.; Dalaklis, 2017).

Under this regulation, the Designated Authority must verify that port and port-terminal operators (port facilities) hire properly certified Port Security Officer (PSO) and Port Facility Security Officer (PFSO) to develop the PSA/PFSA and respective PSP/PFSP, which shall be revised, amended if necessary and approved by the Designated Authority upon implementation. "Once PSP/PFSP are implemented, the designated authority is also responsible for conducting inspection to confirm that all requirements and measures established in the plan are implemented at the respective facility. Then and only then, the Designated Authority may issue the respective Statement of Compliance (SoC), which shall not exceed a period of five years" (Nordfjeld Ávila-Zúñiga, 2018). The responsible person for the continual compliance of the PSP/PFSP is the Port Security Officer (PSO) or Port Facility Security Officer (PFSO), including all requirements established in the ISPS Code and reflected in the PSP/PFSP as training and certification, exercises, practices, inspections audits and modifications via formalised procedures to the plan. In addition, they must attend and respond to security incidents and keep incident security records updated, which must be considered in the risk evaluation and integrated into the security plan to achieve a constant reduction of risks and the continuous improvement of port and maritime security (Nordfjeld Ávila-Zúñiga, A.; Dalaklis, 2017).

According to the IMO, there are certain types of security incidents that are considered serious and must be immediately reported to the Designated Authority and considered for an update of the PFSA/PFSP. These include the following:

- Terror attacks,
- Bomb warnings,
- Hijack,
- Armed robbery against a ship,
- Discovery of other weapons,
- Discovery of explosives,
- Unauthorized access to a restricted area,
- Unauthorized access to the port facility (International Maritime Organization, 2012).

The IMO established three different security levels through SOLAS Chapter XI-2 and the ISPS Code: Security Level 1 (normal) requires the minimum protective security measures at all times. Security Level 2, which requires additional protective security measures for the specific period of time that the risk of a security incident is present and; Security Level 3, which requires high specific protective security measures and may imply the suspension of commercial operations. Security response under Level 3 is transferred to the Government or other organizations responsible for dealing with significant incidents, as explained by the International Maritime Organization (International Maritime Organization, 2002a; 2012) as cited by (Nordfjeld Ávila-Zúñiga, 2018).

According to the research by Cedergren, A. & Tehler (2014), there is, in risk governance, a need to take into account the ways in which risk-related decision-making is performed in settings where many stakeholders are involved, and where these different stakeholders may hold diverse meanings of the concept of central concepts such as risk (Rasmussen, 1985). Therefore, diverse aspects related to maritime security risk governance, such as those indicated by Cedergren & Tehler (2014) and exemplified in Figure 1 below, must be considered in to the NMSA and respective NMSP.

To understand maritime security challenges, it is necessary to define plausible, relevant and challenging threats and scenarios. Qualitative aspects to consider when choosing scenarios include that there should be multiple scenarios to account for uncertainty and each scenario must be plausible, internally consistent, relevant, and contribute to the analysis (Liwång, 2015).

The existing research in maritime security is limited. However research, such as Bichou (2008); (Liwång, H.; Ringsberg, J. W. & Norsell, M. 2013); Liwång, H.; Ringsberg (2013) and (Psarros , et al. (2011), show that empiric data on the shipping system as well as on specific incidents is needed to be able to discuss measures and risk control options. It is also clear from the previous research on society protection in general, such as Cedergren & Tehler (2014), and on maritime security specifically, such as Schneider (2012), that measures are needed on several different levels of the system (Cordner, 2014).

Figure 1: Example: maritime security risk governance in the littoral and at open sea, three conceptual levels of abstraction and four typical stakeholder levels. developed from a generic description of the Swedish risk and vulnerability assessment system by Cedergren & Tehler (2014) and the hierarchical knowledge representation.

Stakeholder levels / Levels of abstraction	**Ships at sea**	**Installations at sea**	**National security enforcing agencies**	**Responsible government control agencies**	**International maritime security framework**
Purpose	Safeguard crew and operation	Safeguard the installations	Work for reducing security risks	National overview of risk	International overview of risk.
Function	Ship security management	Security management	Fight crime and provide for a maritime picture	National risk identification	International risk identification
Form	Implementation of risk controls based on a risk analysis	Unclear	Controls, surveillance and information sharing	Risk assessment and control of security plans	International maritime security codes

Source: Rasmussen, 1985.

3. The Port Facility Security Assessment (PFSA).

The PSA/PFSA is a risk assessment of security threats related to the port or port facility. It includes an analysis of its vulnerabilities and security measures to mitigate such risks, and it forms the basis for the development and updating of the PSP/PFSP. Nordfjeld Ávila-Zúñiga, (2018), explained that among the maritime security measures established by the IMO is the requirement of a periodical revision/update and improvement of PSA/PFSA taking into consideration changes in security threats, changes in the port facility operations, infrastructure or other relevant subjects and after security incidents. The Designated Authority shall also determine the frequency for review of approved PSA/PFSA, while common practice is to review them once a year and in the case of some of the following events: "a) significant security incident at the port/port facility; b) change in the shipping operations undertaken at the facility; and or c) change of facility owner or operator" (International Maritime Organization, 2012).

The IMO establishes certain requirements for the development of PSA/PFSA that include the following elements:

1. Identification and evaluation of important assets and infrastructure;
2. Identification of possible threats to them and the likelihood of their occurrence;
3. Identification, selection and privatization of countermeasures and procedural changes and their level of effectiveness in reducing vulnerabilities; and
4. Identification of weaknesses, including human factors, in the infrastructure, policies and procedures" (International Maritime Organization, 2012).

The PSA/PFSA is built on a six phase assessment:

- Pre-assessment
- Threat assessment
- Impact assessment
- Vulnerability assessment
- Risk scoring
- Risk management

Likewise, with the objective of establishing a standardised method worldwide and considering security measures at a minimum level, the IMO recommends the following formula to score the risk accurately:

RISK = THREAT x IMPACT x VULNERABILITY

However, contracting governments to the SOLAS 1974 Convention are free to demand stricter regulations and requirements for higher security measures than those established by the IMO (which are considered to a minimum level).

In their previous study, Nordfjeld Ávila-Zúñiga (2018), explained that "the method suggested by the IMO assigns a score for the different threat scenarios considering its likelihood of occurrence if there is/was not security measures or score 1 to improbable; score 2 to unlikely; score 3 to likely; and score 4 to probable. Concerning the impact, again allocated on specific criteria, the scores are the following: score 1 to minor; 2 to moderate; 3 to significant and; 4 to substantial. For the assessment of vulnerabilities, targets, strengths, weaknesses, predictability and vulnerability, among other aspects, are included in the analysis where factors as countermeasures and mitigating controls are highly considered, transforming the vulnerability assessment into a vulnerability score. The IMO suggest the following subjective method to allocate a score to vulnerability regarding the extent of risk management: score 1 to robust and effective, (for the case where a complete set of countermeasures is implemented); score 2 to acceptable, (for the case where sufficient countermeasures are implemented to reduce the threat or security risk to an acceptable level); score 3 to limited, (for the case where some countermeasures are implemented and); 4 to none (for the case where none countermeasures or mitigating controls are implemented)".

An imaginary example based on this formula can be developed for the Port of Coatzacoalcos, Mexico, in the Gulf of Mexico: This has been allocated with a Threat Score 3 (considering the illegal activities of drug organizations, oil theft, piratical attacks and organized crime in the area). Then it would be allocated an Impact Score of 4 (considering the critical infrastructure for the energy sector) and a vulnerability of 3 (considering that some security measures and mitigating controls are implemented to prevent the occurrence of security incidents to certain extent but not to an acceptable level). Then, the Residual Risk Score would be 36, equal to 3x4x3.

After common practice, the Residual Risk is classified into three different categories: "high for a Residual Risk Score of 27 and above; medium for a Residual Risk Score of 8-24 and; low for a Residual Risk Score of 6 or less" (International Maritime Organization, 2012). "Threats, impact and vulnerabilities are carefully analysed during the development of the PSA/PFSA, in which must also be included the evaluation of necessary security measures and mitigating controls to reduce the risk to an acceptable level on a sustainable long term bases. If the result of a PSA/PFSA is a high Risk Residual Score it shall be evaluated to include further security measures and stricter mitigating controls; while in the case of a medium Residual Risk Score, the risk and/or threats shall be monitored continuously. For the case of a low Residual Risk Score, there is no need for further security measures" (Nordfjeld Ávila-Zúñiga, 2018).

4. Cybersecurity threats & the PFSA.

Cybersecurity within the maritime context is not limited to prevent cyber-attacks or stopping hackers from gaining access to the operational and information systems, but it also includes protection of digital assets and data, to ensure the continuity of global trade, while ensuring that the maritime industry has the capacity to avert external and internal cyber-security-threats.

Maritime cybersecurity has been defined as "the collection of tools, policies, security concepts, security safeguards, guidelines, risk management approaches, actions, training, best practices, assurance, and technologies used to protect maritime organizations, their vessels, and their cyber environment by Missionsecure (2022). According to the IMO (2022), maritime cyber risk refers to "a measure of the extent to which a technology asset could be threatened by a potential circumstance or event, which may result in shipping-related operational, safety or security failures as a consequence of information or systems being corrupted, lost or compromised".

Operational Technology (OT) and Information Technology (IT) are quite different regarding attack outcomes. Missionsecure (2022), explained that an attack on IT could lead to data theft, while an attack on OT could lead to injury or loss of life, asset damage, or environmental impact. The authors raised concerns about "traditional cybersecurity measures that fail to protect vessels from cyber-attacks and leave the OT network exposed, falling short on providing the visibility and protection required for cyber-physical processes underlying in the maritime industry". The authors highlighted that the complexities associated with vessels and tankers make them vulnerable to high-impact attacks that could last for weeks and spread malware to sister vessels via the corporate network. They previsedthat some of the potential attacks that can cripple a vessel's operations include the following:

- An attack on an OEM network or third-party supplier that spreads to their client's on-vessel OT network,
- An attack on a satellite provider that gains access to a vessel's IT/OT network,
- Exploited cyber vulnerabilities that grant access to a vessel's OT network and provide various attack options, including:
  - GPS/navigation system attack
  - Open/close critical valves
  - Propulsion and rudder control
  - Ballast control
  - Ransomware/Malware
  - Gain full administrative privileges Missionsecure - (2022).

The IMO Maritime Safety Committee (MSC) adopted Resolution MSC.428(98) on Maritime Cyber Risk Management in

Safety Management Systems in June 2017 (International Maritime Organization, 2017). The resolution states that an approved safety management system should include cyber risk management in accordance with the objectives and requirements of the ISM Code, no later than the first annual verification of a company's Document of Compliance after 1 January 2021. From 2021, ship-owners and operators must incorporate cyber risk into ships' safety management systems and appoint a Cyber Security Officer (CySO) on board all ships that shall develop the Cyber Security Assessment (CSA) and the respective Cyber Security Plan (CSP), which is part of the Ship Security Plan (SSP), developed by the Ship Security Officer (International Maritime Organization, 2017). Cyber-security risks must also be considered in the PFSA.

5. Research Methodology.

The research methodology of the current study is focused on adapting the standardised method worldwide, recommended by the IMO to score the risk accurately and included into the International Ship and Port Facility Security Code (ISPS Code), which is the following: RISK = THREAT x IMPACT x VULNERABILITY

This study proposes to adapt and expand this formula to include all ports from a respective country, which along with the necessary programming application can then calculate in real time the total residual risk for all ports of the selected country, provided that the security level is properly updated at all times. The suggested mathematic model is the following:

$$R = \frac{1}{|S|} \sum_{x \in S} T_x I_x V_x$$

It is necessary to clarify that in the suggested model the variables are as follows; R means the total residual risk for the country, while T correspond to Threats, I to Impact and V to vulnerabilities, while S is the set of ports. Based on this equation, a relevant information technology program was created by allocating a variable for each of these factors at each of the ports, at each of the "imaginary encoded" countries, due to the fact that information related to threats, impacts and vulnerabilities at ports is commonly classified as highly confidential.

The programme was created and tested with the possibility to add as many countries as desired and include as many ports in each of the countries as necessary and then, as many port terminals at each port as needed. For testing purposes, a number of five countries was used; each of them associated with three ports and three respective port facilities/port terminals.

6. Results.

The results for the five "imaginary" countries are presented in the figures below. Figure 2 indicates the total residual risk for each of them (A, B, C, D and E) under the column called "average", which is the median for the risk of the associated ports (Port 1, Port 2 and Port 3). These numbers at a country level are also presented in Figure 3, in pie chart format to see it from a general risk comparative perspective. As mentioned before, the programme was developed and tested with the possibility to add as many countries as desired and as many ports in each of the countries as necessary and then, as many port terminals at each port as needed. However, for testing purposes, the number of countries was limited to five with three ports and three respective port facilities/port terminals for each of them.

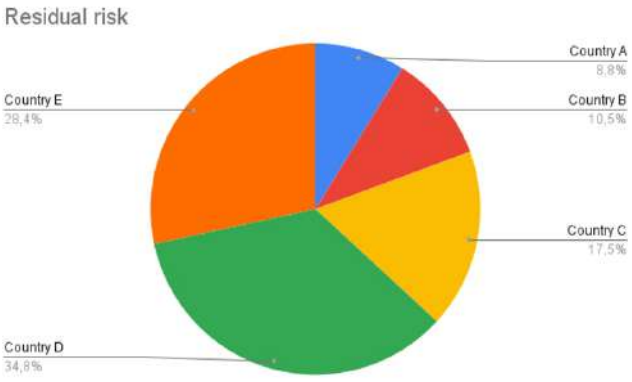
Figure 2: Residual Risk for countries maritime security.

Back | Add country

	Port 1	Port 2	Port 3	Average
Country A	7.5	4.4	2.1	4.7
Country B	11.9	2.9	2.0	5.6
Country C	13.7	7.4	6.8	9.3
Country D	11.3	12.3	32.0	18.5
Country E	15.0	29.3	1.0	15.1

Source: Authors.

Figure 3: Residual risk for countries represented in percent.



Source: Authors.

Figure 2 shows the part of risk for each country in percent, in a scenario where the world is represented with only five countries. The figure 2 and 3 presenting the residual risk for country-level is followed by figures 4, 5, 6, 7 and 8, in which by allocating an "imaginary" value to variables T (Threats), I (Impact) and N (vulnerabilities) for the respective terminal (Terminal1, Terminal 2 and Terminal 3), it is possible to calculate the residual risk for the respective facilities, which then are used to calculate the residual risk for the whole port (Port 1, Port 2 and Port 3).

As mentioned before, the Residual Risk is classified into three different categories: "high for a Residual Risk Score of 27 and above; medium for a Residual Risk Score of 8-24 and; low for a Residual Risk Score of 6 or less" (International Maritime Organization, 2012). Thus, in our model we used the red colour to illustrate countries, ports and terminals with a high residual

risk, yellow to demonstrate medium and green for a low level.

Figure 4: Residual Risk for Ports and terminals of Country A.

Back | Add port

	Terminal 1	Terminal 2	Terminal 3	Average
Port 1	0.4	21.3	0.8	7.5
Port 2	3.4	9.7	0.0	4.4
Port 3	0.0	0.7	5.5	2.1

Source: Authors.

Figure 5: Residual Risk for Ports and Terminals of Country B.

Back | Add port

	Terminal 1	Terminal 2	Terminal 3	Average
Port 1	22.7	12.7	0.3	11.9
Port 2	1.4	1.8	5.6	2.9
Port 3	1.4	4.4	0.1	2.0

Source: Authors.

Figure 6: Residual Risk for Ports and Terminals of Country C.

Back | Add port

	Terminal 1	Terminal 2	Terminal 3	Average
Port 1	18.7	11.9	10.5	13.7
Port 2	7.2	4.1	10.8	7.4
Port 3	9.8	10.5	0.1	6.8

Source: Authors.

Figure 7: Residual Risk for Ports and Terminals of Country D.

Back | Add port

	Terminal 1	Terminal 2	Terminal 3	Average
Port 1	1.0	1.0	32.0	11.3
Port 2	1.0	18.0	18.0	12.3
Port 3	48.0	24.0	24.0	32.0

Source: Authors.

Figure 8: Residual Risk for Ports and Terminals of Country E.

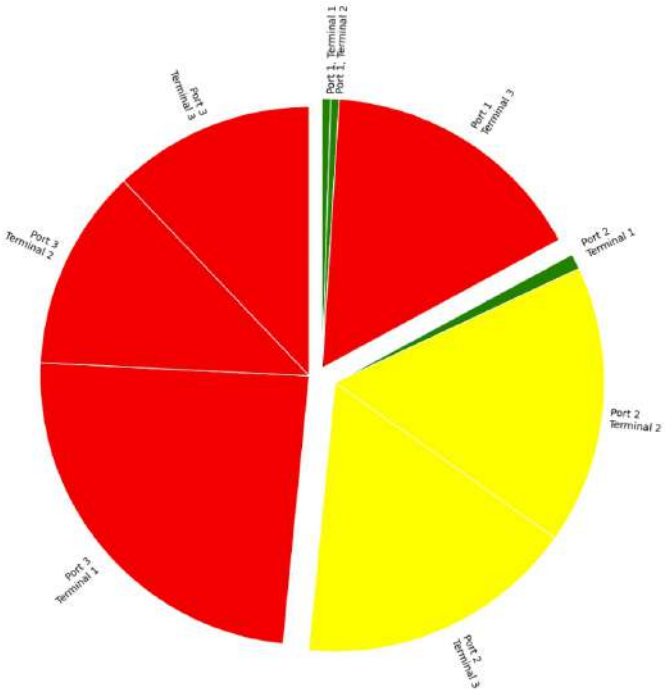
Back | Add port

	Terminal 1	Terminal 2	Terminal 3	Average
Port 1	12.0	24.0	9.0	15.0
Port 2	36.0	36.0	16.0	29.3
Port 3	1.0	1.0	1.0	1.0

Source: Authors.

As explained before, this model provides an overview of the residual risk both at national level and at each port, which would allow the concerned authorities to improve situational awareness adapting to security changes through a better planning of human, economic and material resources to deter maritime security threats. For example, in the case of A and B, the aspects and countermeasures established in ports 2 and 3 (which have a really low risk level), respectively should be assessed to evaluate if some human and material resources as sea patrols could be moved to port 1 to reduce the risk from medium to low level. Another example is country E, where resources for countermeasures in port 3, with a residual risk of 1 should be evaluated for rotation to port 2, which reports a quite high risk with significant security threats. Likewise country D, where Port 3 presents a very high residual risk level (with three terminals in red, figure 9 below) countermeasures should urgently be implemented.

Figure 9: Risk analysis for country D in pie chart.



Source: Authors.

7. Discussing the Swedish Perspective.

Sweden is here used an example of the role of Residual Risk for maritime security could play in the maritime security risk governance for a nation.

In Sweden, the public debate regarding maritime security has mostly been limited to piracy off Somalia and legal aspects of armed guards on ships, two issues with little relevance for maritime security in European waters. However, outside the public eye there have also been specific studies, analyses and exercises initiated by Swedish government agencies such as the Swedish Maritime Administration (Swedish Maritime Administration, 2006), the Swedish Radiation Safety Authority (the exercise Pilot 2015) and the Swedish Armed Forces (a staff exercise regarding maritime security 2016) and academic studies (see for example University of Helsinki, 2009).

These exercises typically deal with a single terrorist attack against a ship under the Swedish flag and includes several organizations and government agencies. However, it does not represent a complete maritime security system perspective based on the nation's maritime strategic security needs.

Moreover, to reduce the identified challenges there is a need for a systems approach that examines different aspects and levels of the maritime security system and how the system delivers utility to a nation or region. A nation's maritime administration has a central role to play and to fully comply this role it is necessary that they have a clear national maritime security strategy, according to a national maritime security assessment, followed by a national maritime security plan, since also other stake holders take decisions that greatly affect maritime security. Such stake holders include ship operators as well as law enforcement agencies that both lack a system level knowledge. This aspect presents specific challenges for the region, nation, and organization responsible for ensuring sufficient maritime security. It also means that the focus is on a nation's (or set of nations and nations' international cooperation) capabilities and efforts needed.

Several Swedish studies have indicated a need for strengthening national transport coordination in response to crises, both as a result of a disruption of the transport system itself (Mötesplats Transporter, 2009; Samverkansområdet Transporter, 2007; Swedish Civil Contingencies Agency, 2014; Swedish Maritime Administration, 2012), but also to avoid that a crisis in other areas and sectors affect the transport system (Samverkansområdet Transporter 2007; Swedish Civil Contingencies Agency, 2014; Swedish Maritime Administration, 2013 and 2014). However, specific Swedish efforts for maritime security are hard to identify.

Previously to this study, the authors intended to develop an analysis over the current status of maritime security in Sweden. Public official and updated maritime security incident statistics is not readily available. Several institutions were contacted to collect data, finding at first glance that there is a significant lack of awareness and knowledge about types of security incidents versus safety accidents or the so-called safety near-misses. Therefore, there is very little evidence of that, and how, the Swedish government agencies implement and enforce maritime security (other than administrative tasks in relation to the ISPS Code) according to Figure 1.

Maritime security threats such as the following, among others, must be considered for the case of Sweden:

1. Transnational organized crime on board ferry traffic between Sweden and Finland
2. Weapons smuggling from the Baltic
3. Drug smuggling from the Baltic
4. Fishing disputes
5. Violation of Swedish waters

Given today's agency structure and responsibility, a risk governance approach is needed and the maritime security efforts need to be further developed and coordinated. Such coordination could efficiently by achieved through a national maritime security assessment (NMSA) and the respective development of a national maritime security plan (NMSP).

Only with a systematic description and understanding of the maritime security system as a whole and at a national level can the performance of the different stakeholders be assessed in relation to their duties and coordination of response to a serious maritime security threat. Therefore, there is a need for an enhanced knowledge on how different stakeholders can strengthen the maritime security system establishing clear duties and responsibilities, including information sharing in the NMSP, which must consider all threat scenarios and deterrence actions evaluated in the NMSA.

Conclusions and recommendations.

1. As a result of the risk-based approach of ISPS Code implementation and enforcement applied at port facility and ship level, it would be extremely beneficial to further develop it to a countrywide level by applying a national and holistic approach to improve not only the assessment of security risks but also manage human, economic and material resources in relation to the identified maritime security threats.
2. The mathematical dynamic model proposed in this paper can provide an effective tool to administer maritime security at the national level, since it calculates in real time the residual risk for the whole country and each of its ports by adapting and expanding the formula and procedures established in the ISPS Code.
3. Due to the fact that the ISPS Code and related instruments have already been implemented by contracting governments to the SOLAS 1974 Convention at all their maritime ports (on the minimum on those that serve international trade needs), the proposed model could facilitate the use of this quantitative solution to administer maritime security risks on a national basis and build the consequent national maritime security plan, which would allow the national authorities to improve situational awareness and adapt to security changes through a better planning.

4. The implementation of this model along with the necessary programming application is recommended as very suitable to manage maritime security at a national level, considering that this methodology is relatively easy to implement and it could considerably strengthen robustness in maritime and national security.
5. An extended version of this model could also be used by the IMO – perhaps through its Global Integrated Shipping Information System (GISIS) – as a way to keep an overview of the general risk at each of its member states (running the model at a country level), assuming that states share with IMO their NMSA and keep these updated at all times.

Future research direction and recommendations.

Future research directions could include the adaptation, development and implementation of the ISPS Code procedures to cover critical infrastructure inland to expand this national maritime security assessment to a general national security assessment.

References.

Bichou, K. (2008). Security and risk-based models in shipping and ports: review and critical analysis. Issue Joint Transport Research Centre Discussion Paper, 20.

Cedergren, A.; Tehler, H. (2014). Studying risk governance using a design perspective. Safety Science, 68(0), 89–98. https://doi.org/10.1016/j.ssci.2014.03.006.

Centre of Excellence for Operations in Confined and Shallow Waters North Atlantic Treaty Organization. (2013). Maritime Situational Awareness. https://www.coecsw.org/our-work-/projects/maritime-situational-awareness/.

Cordner, L. (2014). Risk managing maritime security in the Indian Ocean Region. Journal of the Indian Ocean Region, 10(1), 46–66. https://doi.org/10.1080/19480881.2014.882148.

Council of the European Union. (2014). European Union maritime security strategy (11205/14) (24 June 20).

Homeland Security of the United Sates. (2022). National Strategy for Maritime Security. https://www.dhs.gov/national-plan-achieve-maritime-domain-awareness.

International Maritime Organization. (2002a). Amendments to the Annex to the International Convention for the Safety of Life at Sea, 1974, as Amended. SOLAS/CONF.5/32 ANNEX 2002a.

International Maritime Organization. (2002b). Conference Resolution 2 (adopted on 12 December 2002) Adoption of the International Code for the Security of Ships and Port Facilities. SOLAS/CONF.5/34 ANNEX 1. 2002 b.

International Maritime Organization. (2012). Guide to maritime security and the ISPS Code. International Maritime Organization.International Maritime Organization. (2017). Resolution MSC.428(98) (adopted on 16 June 2017) Maritime Cyber Risk Management In Safety Management Systems. https://www-.cdn.imo.org/localresources/en/OurWork/Security/Documents/-Resolution MSC.428(98).pdf.

International Maritime Organization. (2022). Maritime cyber risk. https://www.imo.org/en/OurWork/Security/Pages/Cybersecurity.aspx.

Kenneth, C. (2009). Port security management. CRC Press Taylor & Francis Group.Liwång, H.; Ringsberg, J. W.; Norsell, M. (2013). Quantitative risk analysis - Ship security analysis for effective risk control options. Safety Science, 58, 98–112. https://doi.org/https://doi.org/10.1016/j.ssci.2013.04.003, 98–112. doi:https://doi.org/10.1016/j.ssci.2013.04.003.

Liwång, H.; Ringsberg, J. W. (2013). Ship security analysis - The effect of ship speed and effective lookout. Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering - OMAE, 2 A. https://doi.org/doi:10.1115/OMAE-2013-10166.

Liwång, H.; Sörenson, K.; Österman, C. (2015). Ship security challenges in high-risk areas: manageable or insurmountable? WMU Journal of Maritime Affairs, 14(2), 201–217.

Liwång, H. (2015). Risk-based ship security analysis – a decision-support approach. Chalmers University of Technology.

Maritime Security Policy Coordinating Committee Of The U.S. (2005). National Plan to Achieve Maritime Domain Awareness for the National Strategy for Maritime Security. https://www.dhs.gov/xlibrary/assets/HSPD_MDAPlan.pdf.

Mejia, M. (2007). Law and Ergonomics in Maritime Security. Department of Design Sciences, Lund University.

Missionsecure. (2022). A Comprehensive Guide to Maritime Cybersecurity. https://www.missionsecure.com/maritime-security-perspectives-for-a-comprehensive-approach

MNE Multinational Experiment 7. (2012). Maritime security regime concept.

Mötesplats Transporter. (2009). Samverkan, samordning & samarbete, Nyckelord för fortsatt arbete [Collaboration, coordination and cooperation, Keywords for continued work].

Nordfjeld Ávila-Zúñiga, A.; Dalaklis, D.; Mejia Jr, M. Q.; Neri, K. (2021). Applying the Legal Provisions of the ISPS Code to Streamline Cooperation between Government Authorities Involved in Maritime Security Duties. In M. Musi (Ed.), An Overview of Transport Law Regulatory Policies: The Search for New Answers to Old Problems and Possible Solutions to the Challenges Posed by Technological Evolution, the Pandemic, and Brexit. Bonomo Editore.

Nordfjeld Ávila-Zúñiga, A.; Dalaklis, D. (2017). Enhancing maritime security in Mexico: Privatization, militarization or a combination of both? In P. Chaumette (Ed.), Economic challenge and new maritime risks management: What blue growth? (pp. 81–101). Gomylex.

Nordfjeld Avila-Zúñiga, A. (2018). Building a National Maritime Security Policy. World Maritime University. WMU Research Report Series. https://commons.wmu.se/phd_dissertations/11/.

Nordfjeld Ávila-Zúñiga, A. . D. D. (2018). Assessing the Need of Implementing ISPS Code instruments to Customs Maritime Units, 2018b. In M. Musi (Ed.), Maritime and Transport Law: Between Legacies of the Past and Modernization (pp. 243–260). Bonomo Editore.

Psarros, G.; Christiansen, A.; Skjong, R.; Gravir, G. (2011). On the success rates of maritime piracy attacks. Journal of Transportation Security, (4, Ed.). https://doi.org/https://doi.org/-10.1007/s12198-011-0073-4.

Rasmussen, J. (1985). The role of hierarchical knowledge representation in decisionmaking and system management. IEEE Transactions on Systems, Man and Cybernetics, 15(2), 234–243.

Rudner, M. (2009). Protecting Canada's critical national infrastructure from terrorism. International Journal, 775–797.

Samverkansområdet Transporter. (2007). Öresundsstudien 2006 [The Øresund study 2006].

Schneider, P. (2012). German maritime security governance: a perspective on the Indian Ocean Region. Journal of the Indian Ocean Region, 2, 142–164. https://doi.org/10.1080/19480881.-2012.730749.

Secretary of Defense USA. (2012). Sustaining U.S. global leadership: Priorities for 21st century defense.

Swedish Civil Contingencies Agency. (2014). Research for a safer society – New knowledge for future challenges MSB's research strategy.

Swedish Maritime Administration. (2006). Risk och sårbarhetsanalys för sjöfartssektorn 2005 [Risk and vulnerability analysis for the shipping sector 2005].

Swedish Maritime Administration. (2012). Risk och sårbarhetsanalys för sjöfartssektorn 2012 [Risk and vulnerability analysis for the shipping sector 2012].

Swedish Maritime Administration. (2013). Årsredovisning 2012 [Year Revision 2012, in Swedish].

Swedish Maritime Administration. (2014). Sjöfartsverkets risk och sårbarhetsanalys 2014 [The Swedish Maritime Administration's risk and vulnerability analysis 2014].

Till, G. (2009). Maintaining good order at sea. In Seapower: a guide for the twenty-first century (Second ed., pp. 286–321). Routledge.

University of Helsinki. (2009). Preventing Terrorism in Maritime Regions - Case Analysis of the Project Poseidon. In & P. V. T. In Hellenberg (Ed.), Aleksanteri Papers. University of Helsinki.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 133–145

ISSN: 1697-4840, www.jmr.unican.es

System Dynamics for Smart Defense System of the Archipelago Sea Defense in Indonesia

Eska Y. Wiratama[1], Yoyok Nurkarya[1], I Made Jiwa A.[1], Joko Purnomo[1], A.K. Susilo[1,*]

ARTICLE INFO

Article history:
Received 03 Jun 2023;
in revised from 04 Jul 2023;
accepted 04 Sep 2023.

Keywords:
Smart Defense; Delphi; Fuzzy Weighting; System Dynamic. .

ABSTRACT

The modeling of Smart Defense for the Indonesian Maritime Defense Strategy is determined by the influence and interconnected interaction among various aspects as a complex system. Hence, a comprehensive analysis is needed to evaluate the Smart Defense for the Indonesian Sea Defense Strategy from the perspectives of Technology, Operational Strategy, Indonesian Navy Posture, and Threat Perception. To assess the value of Smart Defense capabilities, a dynamic model is developed to project the value of the Indonesian Maritime Defense Strategy over a period of five years. In this paper, the researcher constructs a model using a Dynamic Systems approach integrated with the Delphi method to determine the influential criteria for smart defense in the maritime defense strategy, and the Fuzzy Weighting method is employed to obtain the value of smart defense capabilities based on the aspects of Technology, Operational Strategy, Indonesian Navy Posture, and Threat Perception. The formulated model and simulation results using the System Dynamic approach reveal that the value Smart Defense of the Archipelago Sea Defense Strategy is projected to be 86.8% (Capable/Excellent) in the year 2023 and is expected to increase to 88.8% (Capable/Excellent) by the fifth year, entering 2028. Thus, based on these findings, the Indonesian Maritime Defense Strategy's Smart Defense is still classified as Capable/Excellent.

1. Introduction.

Force development is directed at meeting the needs of the 2020-2044 National Defense System Development, The Indonesian Navy is capable of upholding sovereignty and law in the Indonesian National Jurisdiction area which is guided by the development direction of meeting the 2020-2044 national defense system development needs of the defense of large islands and clusters strategic islands and the surrounding waters within the framework of the Archipelago Marine Defense Strategy and the Indonesian Maritime Defense Strategy (Setiyawan, 2018). Fulfilling the Needs for the Development of the National Defense System for 2020-2044 the required forces of the Indonesian Navy consist of warships, aircraft, bases, and marine combat materials of various types including coastal defense systems and maritime monitoring systems that are deployed at choke points and strategic funnels throughout Indonesia while remaining oriented towards synergistic integration of the three dimensions (Susilo et al., 2019).

The concept and strategy of national defense at sea is also supported by relevant war strategy theories. The increasingly dynamic spectrum of threats caused by Indonesia's geographical constellation and developments in the global and regional strategic environment have been able to be answered by the national defense strategy as outlined in both national legislation and national defense doctrine (Prakoso, 2022).

The maritime defense of the archipelago which is structured in layers of defense are action plans aimed at ensuring the sterility of the territory or territory from enemy forces. In order to carry out this defense strategy, the forces of the sea dimension do not stand alone, it is necessary to optimize the Integrated Fleet Weapons System as well as collaboration, integration and integration of the three dimensions of forces by involving all national resources to carry out sea control as well as anti-access

[1]Indonesia Naval Technology College (STTAL), Surabaya, East Java Indonesia.
[*]Corresponding author: A.K. Susilo. E-mail Address: aprilkukuh53@gmail.com.

and deterrence (Batara, 2023; Dipua et al., 2021).

There are several contributions offered in this research. This study fills a gap in the qualitative analysis of smart defense. Second, this study enriches the literature on smart defense strategies. Third, this research can provide a framework for evaluating the smart defense of the archipelago's maritime defense strategy. Fourth, the development of existing research literature, methodologies and theories as well as technical solutions in promoting smart defense strategies is an additional contribution.

This research consists of several parts. Section 2 provides an explanation of the literature review, including the concept of smart defense and Alfred Thayer Mahan's theory. Section 3 describes the methodology consisting of the research design, the conceptual framework, the Delphi method, the fuzzy-weighting method and the dynamic system model. Section 4 describes the results and discussion, including Identifying Main Variable Aspects of Smart Defense The Archipelago's Sea Defense Strategy, Delphi Method Calculations, Fuzzy Weighting Method Calculations, Model System Dynamic Method. Section 5 is the conclusion of the research, implications, limitations of the research and future research. So in this research we need a strategic structure for the strength of the sea dimension that is able to carry out the defense of the archipelago to deal with every threat both actual and potential and will provide scientific studies by making a dynamic system model of the smart defense system of the archipelago's sea defense strategy to support the duties of the Indonesian Navy.

2. Literature Review.

2.1. Smart Defense concept.

The existence of the national defense system is greatly influenced by the dynamics of the development of the strategic environment and the real conditions of the strength and capability of the national defense system itself (Rowe, 1989). The development of a strategic environment at global, regional and national levels that moves quickly, complexly and dynamically is inseparable from the phenomenon of the rapid development of science and technology which has brought about the world civilization of the Information Age and Industrial Revolution Era 4.0 and Society 5.0 (Azhar, 2022; Thompson, 2011). War and technology always have a causal relationship, meaning that war greatly influences the technological advances of war equipment and vice versa (Greiman, 2020). Future battles will rely on the strength of combat units with a relatively smaller size than now, but far more effective and capable of operating against enemies with high capabilities. The main military equipment system will be more Unmanned Aerial Vehicle (UAV) or unmanned, but with a higher level of autonomy. Military technologies that will develop include: cyber warfare equipment for offensives, more advanced calculation systems, artificial intelligence, etc. (Mustofa, 2022; Raska, 2021). Artificial intelligence or Artificial Intelligence (AI) is an important element of the fourth industrial revolution era. AI technology and applications have a tremendous impact. Artificial intelligence (AI) is an important element of the fourth industrial revolution era. AI technology and applications have a tremendous impact (Payne, 2018). Artificial intelligence (AI) is an important element of the fourth industrial revolution era. AI technology and applications have a tremendous impact (Truong et al., 2020).

2.2. Alfred Thayer Mahan's theory.

Alfred Thayer Mahan, a United States Navy High Officer, in his book "The Influence of Sea Power upon History" put forward the theory that sea power is the most important element for the progress and glory of a country, which if these sea powers are empowered, it will improve the welfare and security of a country. Conversely, if these sea powers are neglected, it will result in losses for a country or even undermine the country (Lord, 2021).

Mahan in his book says that there are 6 elements of "Sea Power" which can make the prosperity and greatness of a nation or country in the sea (Russell, 2006). The elements in question are: 1) geographical position; 2) physical conformation; 3) extent of territory; 4) population; 5) national character; and finally, 6) the character and policy of the government. [25] These divide naturally into two subfields: territory and people.

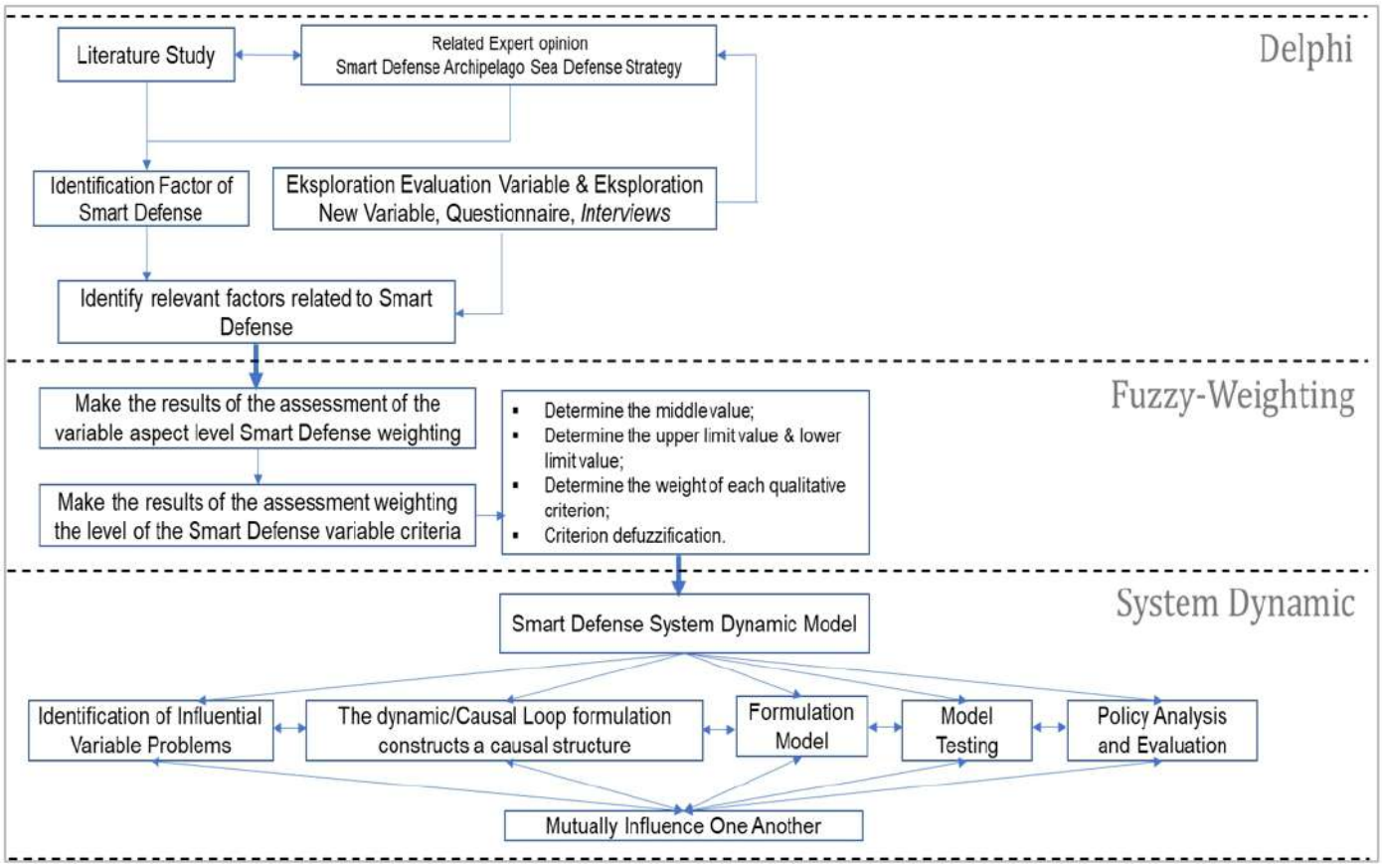
3. Methodology.

The research design in this study is an experimental design, which involves alternative scenarios in the form of changes to the independent variables. The study aims to depict cause and effect within a system and provide a profound understanding of the complex system under investigation. The research design is illustrated as shown in Figure 1 below:

3.1. Delphi method.

Delphi by definition is a group process that involves interaction between researchers and a group of experts on a particular topic, usually through the help of a questionnaire (Cobben et al., 2023; Flanagan et al., 2016). You can find the optimal (maximum or minimum) value for a formula in one cell called the objective cell that satisfies the constraint (constrain), or limit, value in another formula cell on the worksheet. The solver processes a group of cells called decision variable cells which are part of the calculation formula of the objective and constraint cells. In the early stages, the informants will answer based on the information, knowledge and experience they have (Jeyarajan, 2018). The informants provided their answers or opinions with a rating scale between 1 (one) to 9 (nine) based on the level of importance of the instrument to be developed as shown in table 1. With the information that the scale is 1 (very unimportant) and 9 (very important). Furthermore, the results of the assessment from the resource persons were tabulated and processed into the Delphi method formula so that they became a presentation of the results of the agreement of the resource persons group.

Figure 1: Conceptual Framework.



Source: Author.

Table 1: Delphi Rating Scale.

Mark	Information
1-2	Very unimportant
3-4	Not important
5-6	Quite important
7-8	Important
9	Very important

Source: Authors.

3.2. *Fuzzy Weighting Method.*

The data processing uses the Fuzzy weighting algorithm up to level 8 (eight) as follows (Dursun, 2018):

1. Make the results of the weighting assessment of the qualitative aspect variable level.
2. Make the results of the weighting of the assessment of the level of qualitative criteria variables.
3. Determine the middle value of the fuzzy number (), by adding up the values that appear at each level of the linguistic scale and then dividing the sum by the number of aspects or criteria whose values enter that level of linguistic assessment (Zhang & Li, 2011). The mathematical notation is as follows:a_t

$$a_t = \frac{\sum_{i=1}^{k} \sum_j Tij}{\sum_i^k =_{1n_{ij}}} \quad (1)$$

a_t = the mean value of the fuzzy number for the assessment level

Q = very low, low, medium, high and very high rating levels

N = the number of criteria aspects from the Linguistic T scale for the 1st aspect of the i criteria

T_{ij} = the numerical value of the T linguistic scale for the 1st aspect of the jth criterion

1. Determine the lower limit value (ct) and upper limit value (bt) of fuzzy numbers, where the lower limit value (ct = b(i - 1)) is the same as the middle value of the level below it, while the upper limit value (bt = b (i - 1)) is the same as the mean level above it.
2. Determining the aggregate weight of each qualitative criterion, because in this study a form of linguistic assessment was used which already had a triangular fuzzy number definition, the aggregation process was carried out by finding the aggregate value of each lower limit value (c), the middle value (a) and the upper limit value (b), which can be modeled as follows:

$$c_t = \frac{\sum_j^n = 1c_{tj}}{n}, a_t = \frac{\sum_j^n = 1a_{tj}}{n} b_t = \frac{\sum_j^n = 1b_{tj}}{n} \quad (2)$$

Ctj =the lower limit value of the t-th qualitative criteria by the j-th decision maker

a_{tj} = the mean value of the t-th qualitative criterion by the j-th decision maker

b_{tj} = upper limit value of the t-th qualitative criteria by the j-th decision maker

N = number of assessors (decision makers) The aggregate score is N = (where Nt.=aggregation weight value for the t-th qualitative criterionc_j, a_j, b_j)

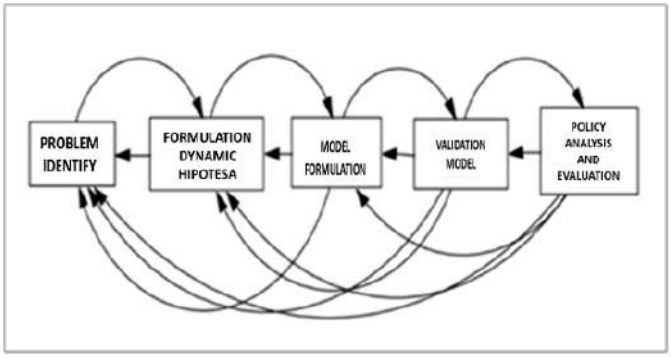
3.3. System Dynamics.

System dynamics (SD) has its origins in the work of engineer Jay W. Forrester. System dynamics modeling can be described primarily as a kind of engineering activity rather than a scientific activity, as it aims at designing deliverables. B. Models, policies, plans, organizational schemes, etc. for concrete situations to be improved under valuable priorities and limited resources. However, philosophy of science is usually used to find the reason for system dynamics (SD) (Olaya, 2019).

It is generally accepted that SD is a powerful tool for analyzing relationships and interactions between variables in a system. This helps in understanding the impact of various factors on the goals defined in the system and provides useful information to decision makers. It is a representative simulation method for evaluating decision-making performance. You can analyze complex interdependencies between variables in your system and improve the accuracy of your evaluation results.Mainly he has three types of variables in the feedback loop (Herrera & Kopainsky, 2020; Tan et al., 2018).This includes equity variables, interest rate variables and auxiliary variables. Inventory variables accumulate flows over a continuous period of time. A velocity variable represents the flow over a period of time. Auxiliary variables identify rate variables. The three types of variables are related by integrals, derivatives, or other types of equations (Tan et al., 2018).

In studying and analyzing the system, we need a method where each component becomes the focus of analysis. One of the superior methods in analyzing systems is system dynamics. In simple terms, the system is defined as a set of components that interact with each other to achieve a certain goal.

Figure 2: Stages in the system dynamic modeling process.



Source: Authors.

4. Results And Discussion.

In this section, data analysis and research results are carried out. The data obtained is in the form of data consisting of primary and secondary data obtained by conducting direct interviews with experts from relevant agencies and also with ship journals in the field. Efforts in data collection are aimed at obtaining valid data so that it can be used according to research objectives. Modeling (Developing).

4.1. Identifying Main Variable Aspects of Smart Defense The Archipelago's Sea Defense Strategy.

The initial stage in the series of developing a smart defense model for the archipelago's sea defense strategy is to identify and collect data on the main aspect variables that influence smart defense. The data was obtained from previous research references and the results of in-depth interviews with experts. Then the next process is to identify the main variables for the smart defense of the archipelago's sea defense strategy, the researcher proposes several aspects that influence the smart defense of the archipelago's sea defense strategy to the experts based on theories in books, previous research and phenomena that occur regarding smart defense strategy maritime defense of the archipelago These aspects are as follows:

After the identification of the main aspect variables and their criteria has been carried out, the next step is to look for the weight of the influence of the importance level of the aspects and variables which constitute a qualitative data obtained from the results of interviews with experts/source persons along with questionnaires from each of these Experts.

4.2. Delphi Method Calculations.

Based on the design of the Delphi method, opinions were drawn from 7 respondents who were experts related to determining the Smart Defense Strategy for the Archipelago's Marine Defense. From the answers to the opinion withdrawal, the answers from the sources were obtained as follows.

From the results of the processing of the Delphi method above, there was a change in position from the previous criteria, namely at the beginning of data collection there were 7 (seven) criteria that became a factor of the smart defense of the archipelago's maritime defense strategy, but after undergoing data processing using the Delphi method it became 4 (four) criteria (average value or average > 7.00). The criteria for processing the Delphi method consist of Technology (K3), Operations Strategy (K1), Indonesian Navy Posture (K2) and Threat Perception (K4) which will be used as the final data for further weighting processing using the next method.

4.3. Fuzzy Weighting Method Calculations.

Next, data processing and looking for weight values influence the level of importance of aspects and criteria in this thesis using a method called the Fuzzy Weighting method (Teniwut et al., 2019), where the processing has levels up to 8 (eight) processing levels. This method has the convenience of filling out questionnaires by Experts/source persons and has a fairly good level of objectivity in determining judgments.

Table 2: Preliminary identification of the main aspects of smart defense in the archipelago's maritime defense strategy.

NO	VARIABLE	DESCRIPTION	REFERENCE
1.	Operational Strategy	The Operations Strategy uses the forces that have been prepared by the Military Strategy. So that the definition of Operations Strategy becomes the art and science of planning, coordinating and controlling military combat within an operational theater in order to achieve the National Goals.	Tomaszewski et al., (2016)
2.	Indonesian Navy Posture	In an effort to organize national defense at sea, the Indonesian Navy carries out tasks which are the embodiment of three roles that are universal, namely the role of the military, the role of constable and the role of diplomacy. The success of carrying out the tasks of the Indonesian Navy will depend on the posture it has.	Susilo et al. (2019)
3.	Technology	The future battlefield environment is increasingly network-based. Network Centric Warfare (NCW) War Center is expected to be converted to C4I-ISR-PGM C4I(Command, Control, Communication & Computer, Intelligence), ISR (Intelligence, Surveillance & Reconnaissance), PGM (Precision Guided Munitions)). This means from detecting the enemy to attacking, consisting of cycles. For this reason, information and communication technology must be the basis, and it will be more effective if it is accompanied by a cyber battlefield environment that can simulate a real battlefield.	Chung et al. (2014)
4.	Threat Perception	Threats that may be faced by the Indonesian Navy in enforcing the law and maintaining the security of the sea area include acts of violence at sea, accidents, navigation and weather, drug smuggling, illegal logging, illegal migrants, Illegal Unreported and Unregulated fishing, illegal mining, pollution sea and fuel smuggling.	Prakoso (2022)
5.	Political	Politics comes from the Greek "polis". Aristotle called his work on state matters "political", then politics means the art of governing and managing the state or state science. Politics includes all policies/actions in state/government affairs including the determination of the forms, tasks and scope of state affairs.	Huang & Billo (2014)
6.	Social and Culture	In general, Social Science and Cultural Sciences belongs to a group of knowledge, namely studying basic knowledge and general understanding of the concepts of human (social) and cultural relations that are developed to study human, social and cultural issues.	Arif & Kurniawan (2018)
7.	Natural Resources	Natural Resources are the elements of the natural environment, both physical and biological, that are needed by humans to meet their needs and improve their welfare.	Dipua et al. (2020)

Source: Authors.

Table 3: Simulation of Expert Opinion Results/source persons.

NO	EXPERT	CRITERIA						
		K1	K2	K3	K4	K5	K6	K7
1	**E1**	8	8	9	9	6	5	5
2	**E2**	9	9	9	8	6	4	3
3	**E3**	7	7	9	9	3	1	1
4	**E4**	9	7	8	7	4	2	1
5	**E5**	9	9	9	8	5	4	4
6	**E6**	9	9	9	8	7	6	7
7	**E7**	8	7	7	6	5	4	6
SCORE		59	56	60	55	36	26	27
MARK		12.70	12.70	14,29	14,29	9.52	7,94	7,94
min		7	7	7	6	3	1	1
MAX		9	9	9	9	7	6	7
AVERAGE		8,43	8.00	8.57	7.86	5,14	3.71	3.86
STD DEV.		0.79	1.00	0.79	1.07	1.35	1.70	2.34
EVALUATION		**CON**	**CON**	**CON**	**CON**	**DIV**	**DIV**	**DIV**

Source: Authors.

The data processing uses the Fuzzy weighting algorithm as follows (Susilo et al., 2020):

a. Make the results of the weighting assessment of the qualitative aspect variable level.
b. Make the results of the weighting of the assessment of the level of qualitative criteria variables.
c. Determine the middle value of the fuzzy number.
d. Determine the value of the upper limit and lower limit of fuzzy numbers.
e. Calculates the aggregate weight of each criterion.
f. Calculating the defuzzy value from the results of the assessment of each qualitative criterion.
g. Calculating the final weight value / level of importance of each aspect variable and criteria.

Table 4: Assessment Aggregate Simulation on Technology Aspects.

NO	CRITERIA	E1	E2	E3	E4	E5	E6	E7
1	Integrated Systems	9	9	9	9	9	8	9
2	Monitoring	9	9	9	9	9	9	9
3	Big Data (IoT, AI & Machine Learning)	9	9	9	9	10	8	9
4	cyber	9	9	9	9	9	8	9
5	Autonomous	7	9	8	9	9	8	9

Source: Authors.

Table 5: Assessment Aggregate Simulation on Operational Strategy Aspects.

NO	CRITERIA	E1	E2	E3	E4	E5	E6	E7
1	Command & control / maritime operation center	9	9	9	9	9	9	9
2	Coastal watch system (radar, ESM electronic support measure, long range camera)	7	7	8	8	8	8	9
3	Mobile surveillance (air, surface, subsurface unmanned vehicle)	8	9	9	9	9	6	9
4	Coastal defense (fixed & mobile missile system, sonar and sonobuoy)	7	5	6	7	6	6	6
5	Integrated air defense	8	9	9	9	9	7	6
6	Anti Submarine Warfare (ASW) defense	8	7	9	8	8	8	7
7	Sea Control	8	7	9	8	7	9	8
8	Human Resources Development	8	7	7	8	8	9	9
9	Risk Management	7	7	7	5	7	9	8
10	Logistics	8	9	8	8	7	8	8

Source: Authors.

Table 6: Assessment Aggregate Simulation on Aspects of Indonesian Navy Posture.

NO	CRITERIA	E1	E2	E3	E4	E5	E6	E7
1	Weapons	9	9	9	8	9	9	9
2	Security, Defense, Intelmar, Diplomacy, Support	8	7	7	8	8	9	8
3	Degree of Operation (Degree of Harvesting / Deployment / routine ops & Degree of Enforcement / Employment 3 trouble spot)	9	7	7	8	8	8	9

Source: Authors.

Table 7: Simulation Aggregate Rating on Threat Perception Aspect.

NO	CRITERIA	E1	E2	E3	E4	E5	E6	E7
1	Air (Aircraft, Drones, Missiles)	8	9	9	8	7	9	7
2	Warships (Surface & Sub Surface)	8	7	7	7	8	9	8
3	Maritime Cyber Security	9	9	9	9	9	9	7

Source: Authors.

Determine the middle value of the fuzzy number (at), by adding up the values that appear at each level of the linguistic scale and then dividing the sum by the number of aspects or criteria whose values enter the linguistic assessment level. The mathematical notation is as follows:

$$a_t = \frac{\sum_{i=1}^{k} \sum_j T_{ij}}{\sum_{i=1}^{k} n_{ij}}$$

a_t = the mean value of the fuzzy number for the assessment level

Q = levels very low, low, medium, high and very high ratings.

N = the number of criteria aspects from the linguistic scale T for the 1^{st} aspect of the i-criteria

Tij= numerical value of the T linguistic scale for the 1^{st} aspect of the j^{th} criterion.Table 8 Aggregate simulation of mid, lower and upper limit values for expert 1 to expert 4.

Table 8: Aggregate simulation of mid, lower and upper limit values for expert 1 to expert 4.

NO	LEVELS LINGUISTIC	E1 ct	E1 at	E1 bt	E2 ct	E2 at	E2 bt	E3 ct	E3 at	E3 bt	E4 ct	E4 at	E4 bt
1	VERY LOW	-	-	-	-	-	-	-	-	-	-	-	-
2	LOW	0.00	3.00	6.00	1.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
3	CURRENTLY	4.00	6.00	7,79	4.00	5.00	7,40	1.00	6.00	7,77	1.00	5.00	7.89
4	TALL	6.00	7,79	9.00	5.00	7,40	9.00	6.00	7,77	9.00	5.00	7.89	9.00
5	VERY HIGH	7,79	9.00	10.00	7,40	9.00	10.00	7,77	9.00	10.00	7.89	9.00	10.00

Source: Authors.

Table 9: Aggregate simulation of mid, lower and upper limit values for expert 5 to expert 7.

NO	LEVELS LINGUISTIC	E5 ct	E5 at	E5 bt	E6 ct	E6 at	E6 bt	E7 ct	E7 at	E7 bt
1	VERY LOW	-	-	-	-	-	-	-	-	-
2	LOW	1.00	3,33	5.91	0.00	0.00	0.00	0.00	0.00	0.00
3	CURRENTLY	3,33	5.91	7,79	3.00	5.69	7,63	3.00	6.00	7,21
4	TALL	5.91	7,79	9.00	5.69	7,63	9.00	6.00	7,21	9.00
5	VERY HIGH	7,79	9.00	10.00	7,63	9.00	10.00	7,21	9.00	10.00

Source: Authors.

The next step is to find the criterion defuzzification value, where the defuzzification method used is the centroid method. The formula for defuzzification criteria is as follows:

$$\text{Defuzzifikasi } N_t = \frac{\left[\left[\int_{c_t}^{a_t} \frac{(x-c_t)}{(a_t-c_t)} x dx + \int_{a_t}^{b_t} \frac{(x-b_t)}{(a_t-b_t)} x dx\right]\right]}{\left[\left[\int_{c_t}^{a_t} \frac{(x-c_t)}{(a_t-c_t)} dx + \int_{a_t}^{b_t} \frac{(x-b_t)}{(a_t-b_t)} dx\right]\right]}$$

with : t = criteria1,2,3.....n.

Table 10: Main Aspect Defuzzy Value (simulation).

No	Key Aspects	Defuzzy Value
1	TECHNOLOGICAL ASPECT	8,099
2	ASPECT OF OPERATIONAL STRATEGY	6,866
3	POSTURE ASPECTS OF THE INDONESIAN NAVY	7,623
4	THREAT PERCEPTION ASPECT	6,985
		29,574

Source: Authors.

Table 11: Technology Aspect Criteria Defuzzy Value (simulation).

NO	CRITERIA	DEFUZZY VALUE
1	Integrated Systems	8,290
2	Monitoring	7,671
3	Big Data (IoT, AI & Machine Learning)	6,575
4	Cyber	7,194
5	Autonomous	6,252
		35,982

Source: Authors.

Table 12: Defuzzy Value Criteria Operational Strategy Aspect (simulation).

NO	CRITERIA	DEFUZZY VALUE
1	Command & control / maritime operation center	6,115
2	Coastal watch system (radar, ESM electronic support measure, long range camera)	4,060
3	Mobile surveillance (air, surface, subsurface unmanned vehicle)	6,020
4	Coastal defense (fixed & mobile missile system, sonar and sonobuoy)	6,194
5	Integrated air defense	5.185
6	Anti Submarine Warfare (ASW) Defense	6,909
7	Sea Control	6,161
8	Human Resources Development	7,290
9	Risk Management	7,671
10	Logistics	6,877
		62,482

Source: Authors.

The next step is processing the defuzzification value into the final weight value for each criterion, by dividing the weight value for each defuzzification criterion by the total number of weight values for all defuzzification criteria.

NB t =*N t*/ΣNt(1-n)

NB t = The final weight value of each criterion

Nt = Defuzzification criterion weight value

ΣNt(1-n) = Sum of the weight values of all defuzzification criteriaTable 15 Key Aspect Weighting Value (simulation)

Table 13: Defuzzy Value of Indonesian Navy Posture Aspect Criteria (simulation).

NO	CRITERIA	DEFUZZY VALUE
1	Weapons	7,671
2	Security	6,575
3	Defense	7,194
4	Intelmar	6,252
5	Diplomacy	6,194
6	Defense Area	5.185
7	Support	6,909
8	Harvesting/Deployment/routine ops degrees	6,233
9	Degree of Enforcement/Employment 3 trouble spot	7,433
		59,647

Source: Authors.

Table 14: Defuzzy Value of Threat Perception Aspect Criteria (simulation).

NO	CRITERIA	DEFUZZY VALUE
1	Air (Aircraft, Drones, Missiles)	5,662
2	Warships (Surface & Sub Surface)	6,652
3	Maritime CyberSecurity	7,194
		19,508

Source: Authors.

Table 15: Key Aspect Weighting Value (simulation).

NO	MAIN ASPECT	FINAL WEIGHT
1	TECHNOLOGICAL ASPECT	0.27
2	ASPECT OF OPERATIONAL STRATEGY	0.23
3	POSTURE ASPECTS OF THE INDONESIAN NAVY	0.26
4	THREAT PERCEPTION ASPECT	0.24

Source: Authors.

Table 16: Technology Aspect Criteria Weighting Value (simulation).

NO	CRITERIA	FINAL WEIGHT
1	Integrated Systems	0.230
2	Monitoring	0.213
3	Big Data (IoT, AI & Machine Learning)	0.183
4	cyber	0.200
5	Autonomous (Ride & Weapon)	0.174

Source: Authors.

The value of the weight of influence (final weight of the simulation) the level of importance of all aspects and criteria for the Smart Defense of the Nusantara Sea Defense Strategy:

1. 0.27 = Value of Technology Aspect.
2. 0.23 = Value of Operational Strategy Aspects.
3. 0.26 = Value of Indonesian Navy Posture Aspect.
4. 0.24 = Value of Threat Perception Aspect.

Table 17: Weighting Criteria Aspect Operational Strategy Value (simulation).

NO	CRITERIA	FINAL WEIGHT
1	Command & control / maritime operation center (Puskodal)	0.0979
2	Coastal watch system (radar, ESM electronic support measure, long range camera)	0.0650
3	Mobile surveillance (air, surface, subsurface unmanned vehicle)	0.0963
4	Coastal defense (fixed & mobile missile system, sonar and sonobuoy)	0.0991
5	Integrated air defense	0.0830
6	Anti Submarine Warfare (ASW) defense	0.1106
7	Sea task force / sea control at ALKI I, II and III	0.0986
8	Human Resources Development	0.1167
9	Risk Management	0.1228
10	Logistics	0.1101

Source: Authors.

Table 18: Indonesian Navy Posture Aspect Criteria Weighting Value (simulation).

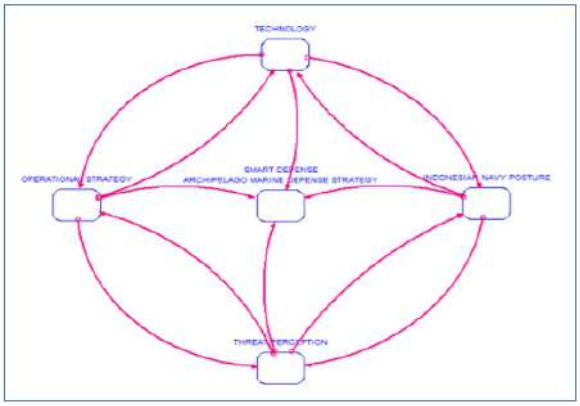
NO	CRITERIA	FINAL WEIGHT
1	Weapons	0.129
2	Security	0.110
3	Defense	0.121
4	Intelmar	0.105
5	Diplomacy	0.1039
6	Dawinhanla	0.0869
7	Support	0.1158
8	Harvesting/Deployment/routine ops degrees	0.104
9	Degree of Enforcement/Employment 3 trouble spot	0.125

Source: Authors.

4.4. Model System Dynamic Method.

Then each of the main aspects as described above has sub-variables and criteria (these variables are explained in the following discussion) so that when a Causal Loop Diagram is compiled it will form a closed system as illustrated in Figure 3 as follows:

Figure 3: Causal loop diagram for all aspects of the smart defense of the archipelago sea defense strategy.



Source: Authors.

In Figure 3 above, the causal diagram explains that the smart defense strategy for the maritime defense of the archipelago is at the midpoint of a system. Where this point is influenced by the main aspect variables and their sub-variables. The sub-variables of each variable interact influence one another, interact and form a dynamic relationship pattern. After obtaining information from experts and other references from various sources as well as previous studies, the next step is to formulate the Smart Defense model for the Nusantara Sea Defense Strategy. This model formulation is structured to be able to see the value of the relationship between variables and their sub-variables that interact and influence one another in a system. Before this model is made in a causal loop diagram, it is necessary to have an explanation of the entity variables from the initial description which can be categorized to make a system model formulation such as stock/level, flow/flow or a converter in a system. For this reason, the researcher then needs to clearly define the description, for naming which parts of the entity are stock/level, flow/flow or a converter so that it is clear what the model maker/researcher wants.

4.5. Model simulation analysis on the Smart Defense of the Archipelago Marine Defense Strategy.

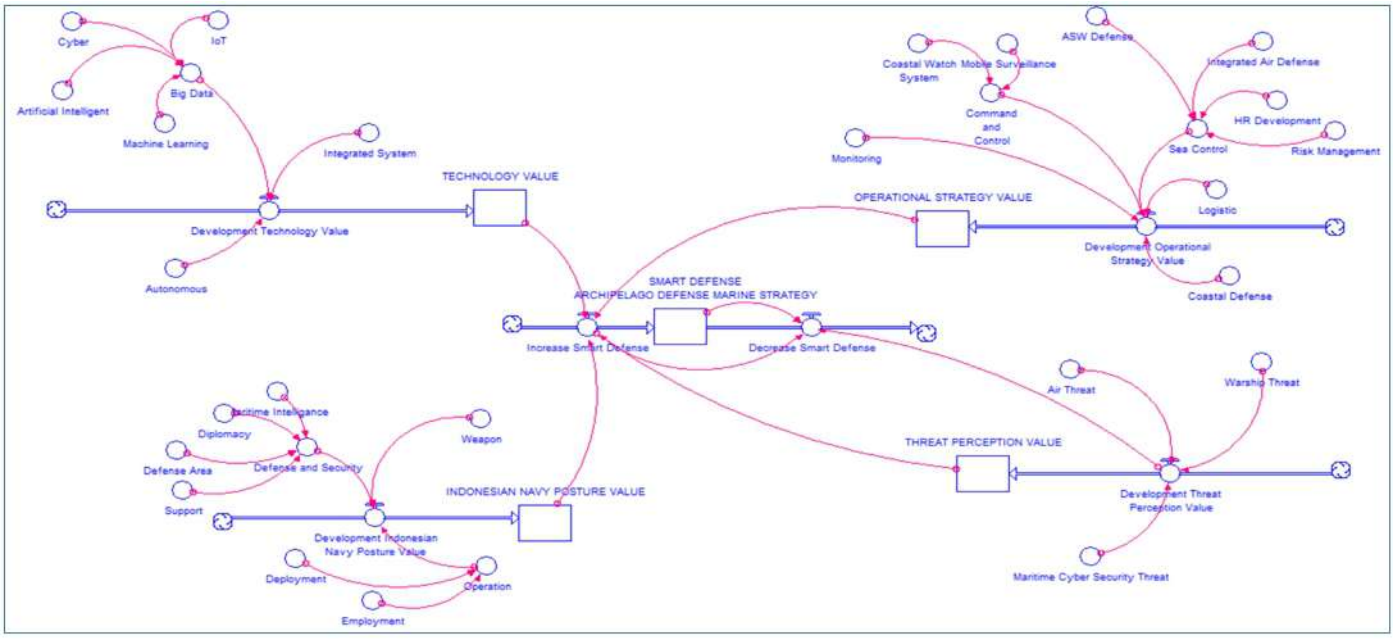
After analyzing the model simulation for each aspect of the Smart Defense Strategy for the Archipelago Sea Defense Strategy which consists of Technology Aspects, Operations Strategy Aspects, Indonesian Navy Posture Aspects and Threat Perception Aspects, then obtaining values from the variables of these four aspects, the next step is to analyze the formulation of the Defense Strategy Smart Defense model. The Archipelago Sea as shown in Figure 4 as follows:

Based on the formulation of this model, the Smart Defense of the Archipelago Sea Defense Strategy is the overall result of the four variable aspects whose values have been obtained and then also integrated with the constant values of the four aspects of the smart defense of the archipelago's maritime defense strategy which are obtained from the weighting results of the influence of the importance level of the four aspects using the Fuzzy Weighting method which has obtained the value from the previous discussion, namely the constant value of the Technology Aspect is worth 0.27, the constant value of the Operations Strategy Aspect is worth 0.23, the constant value of Indonesian Navy Posture is worth 0.26 and the constant value of the Threat Perception Aspect is worth 0.24 which has been measured based on the sub-variables of the four aspects.

4.6. Assessment of Variable Conditions.

In the conceptualization of the model, apart from determining the weight of variable importance, an assessment of the condition of the variables that occurs within a certain period of time is required. Several variables can be assessed according to the parameters used in the model. However, some variables are given assumption values based on linguistic scales that are arranged to equate the parameters used in the conceptualization of the model. The following is a linguistic scale used in the assessment of variable conditions, namely:

Figure 4: Smart Defense Diagram of the Archipelago Sea Defense Strategy All Aspect.



Source: Authors.

Table 19: Linguistic scale of Smart Defense capabilities of the Archipelago Marine Defense Strategy.

Capability	Scale Value	Index value (%)	Strategic Definition
Very low	1.00 – 3.00	0 – 30	Prone to
Low	3.01 – 5.00	30.01 – 50	Alert
Currently	5.01 – 7.00	50.01 – 70	Rational
Tall	7.01 – 9.00	70.01 – 90	Capable (Superior)
Very high	9.01 – 10.00	90.01 – 100	Absolute

Source: Authors.

The table 19 above is the Smart Defense Capability index. The index value in percentage will represent the capability scale value which will be presented in the final score of the Nusantara Sea Defense Strategy's Smart Defense Capability. The following is the value of each aspect based on the smart defense capability index:

The technology aspect has a significant influence on the value of IoT with a rational strategic definition of 62.4%. The results of this value are the output of system dynamics that occur in the IoT value in the technological aspect which is taken according to the index value of the smart defense of the archipelago's marine defense strategy. The Operations Strategy aspect has a significant influence from the value of logistics with a strategic definition of Capable/Excellent 71.6%. The results of this value are the output of system dynamics that occur in the logistics value of the operational strategy aspect which is taken according to the index value smart defense of the archipelago sea defense strategy. The Indonesian Navy posture aspect has a significant influence from the weapon score with a strategic definition of Capable/Excellent 74.8%. The result of this value is the output of the dynamics of the system that occurs in the weapon value on the aspect of the Indonesian Navy's posture which is taken according to the index value of the smart defense of the archipelago's sea defense strategy. The threat perception aspect has a significant influence from the maritime cyber security threat value with a rational strategic definition of 62.8%. The result of this value is the output of system dynamics that occurs in the maritime cyber security threat value on the threat perception aspect which is taken according to the index value of the smart defense of the archipelago's defense strategy.

4.7. Preparation of Policy Scenarios.

The policy scenario is taken based on conditions that allow it to be controlled by Stakeholders / policy makers in this case the Indonesian Navy. In addition, the scenario can be determined based on the variables that affect the main aspect system variables by using a sensitivity test that has been done previously on the sensitivity analysis of system model variables. Sensitivity analysis basically assumes what will happen in real conditions and possible policy choicescarried out by policy makers (Wijaya et al, 2011). Then every parameter change if it is increased or decreased from the basic scenario parameter values, if it is proven that these changes result in real and significant changes to the main parameters, then these parameters will be considered as key parameters (Sterman, 2000).

a. Scenario 1 Technology Aspect with scenario: Integrated system improvement. Where the condition of the integrated system is assumed to be increased by 30%, the following is a graph of the scenario of the relationship between the integrated system and big data variables:

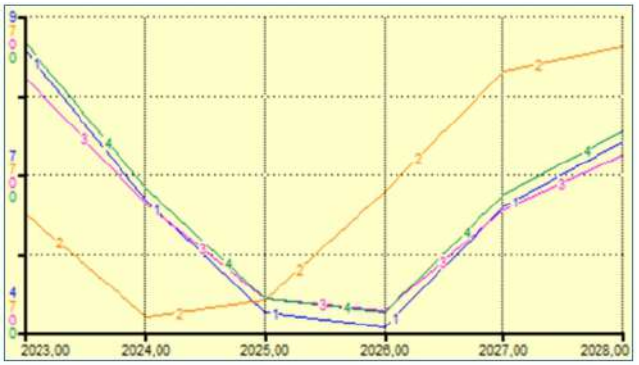
Figure 5: Test Scenario 1 30% increase in the integrated system variable.

Source: Authors.

From the picture above green line is intregated system and orange line is big data variable, after conducting simulations for the period 2023 to 2028. The simulation results show that at the beginning of 2023 to 2026 there is a decrease in the integrated system variable and is followed by the same trend pattern of decline in big data variables, in this condition policy scenarios are planned before late. On the basis of this vigilance, an increase in the integrated system of 30% will only have an impact after 3 years, namely in 2026 and in line with big data variables until 2028 there will be a significant increase, after the policy scenario is implemented. This is none other than due to efforts to increase the variables that affect these technological aspects which will also have an automatic impact on increasing the value of the smart defense of the archipelago's maritime defense strategy going forward.

b. Scenario 2 Aspects of Operations Strategy: increasing logistical variables is a scenario taken in this aspect to be able to find out how it affects the smart defense of the archipelago's maritime defense strategy, so that its sustainability value can later be evaluated. Where the condition of the logistics variable is assumed to have increased by 30%, the following is a graph of the scenario of the relationship between the Smart Defense Value of the Nusantara Sea Defense Strategy and the Aspects of Operations Strategy.

Figure 6: Test Scenario 2 with a 30% increase in logistic variables.

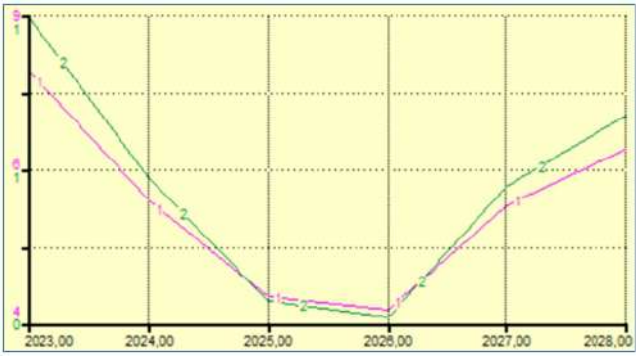


Source: Authors.

From Figure 5 above, blue line is logistic, orange line is smart defense value, pink is command control and the green line is sea control, it can be seen that in the next 5 years it is assumed that the logistic variable has increased by 30%, as can be seen in Figure 5, each variable has experienced a decrease in the first three years, namely 2023 to 2026, then an increase occurred in from 2026 to 2028 due to the 30% increase in logistics policy scenario the impact is starting to be felt so that in the period of 2026 with an increase in logistics or in this case increasing the additional spending budget of the Indonesian Navy, it will also have an impact on increasing command and control variables and sea control variables and giving effect also on the smart defense value of the archipelago's maritime defense strategy.From the scenario engineering results of the developed model, it is concluded that a significant addition to the logistics budget will have implications for increasing the aspects of the operational strategy and the smart defense value of the archipelago's maritime defense strategy.

c. Scenario 3 Aspects of Indonesian Navy Posture: increasing weapon variable is 30% to be able to find out how it affects the security variable.

Figure 7: Scenario 3 test assumes a 30% increase in the weapon variable.

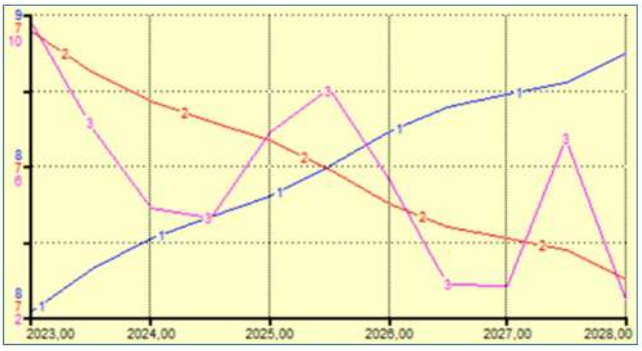


Source: Authors.

Starting from the simulation results from 2023 to 2028 in Figure 6. The simulation results show that at the beginning of 2023 to 2026 there is a decrease in the weapon pink line and green line is security variable and at that time it is also followed by a concurrent decrease in the security variable, responding to these conditions the policy scenario start planning before it's too late. On the basis of vigilance against the decrease in weapon and security variables in the aspect of Indonesian Navy posture, a 30% increase in weapons is carried out, but this will have an effect after the third year, namely in 2026 after the policy scenario is implemented. Therefore weapons consisting of warships, aircraft, Marines, Bases, Marine Special Forces and Personnel can safeguard the interests of the Indonesian nation at sea and guarantee security for sea users.

d. Scenario 4 Aspects of Threat Perception: increase the Maritime Cyber Security variable by 30% to be able to find out how it affects the Smart Defense Value of the Nusantara Sea Defense Strategy.

Figure 8: Test Scenario 4 assuming a 30% increase in Maritime Cyber Security Threat.



Source: Authors.

Observing Figure 7 above in understanding the dynamics of the maritime cyber security variable from 2023 to 2028, blue line is threat perception value, red line is smart defense value and pink line is maritime cyber security threat, where it is assumed that the condition of the maritime cyber security threat variable has increased by 30% actually gives a trend pattern of increasing threat perception values from year to year (2023 to 2028). According to the time movement of the simulation, it appears that there is a close relationship between threat perception and the smart defense of the archipelago's sea defense strategy, namely a negative relationship, when the threat perception increases, the value of the smart defense strategy for the archipelago's sea defense strategy will decrease, and vice versa. The increase in threat perception cannot be separated from the decline in the smart defense of the archipelago's maritime defense strategy.

5. Implication.

The expected theoretical benefits, each stage of the results of this research can produce Smart Defense modeling of the Nusantara Sea Defense Strategy in supporting the tasks of the Indonesian Navy.

The practical benefit is being able to apply dynamic model problem solving with the Delphi, Fuzzy and System Dynamic approaches to modeling smart defense of the archipelago's sea defense strategy in supporting the duties of the Indonesian Navy.

Conclusions

From the simulation and analysis that has been carried out in the previous chapter, the following conclusions can be drawn:

Variables in the main aspects that play an important role in the Smart Defense model of the Archipelago Sea Defense Strategy are as follows 1) On Technology Aspects with integrated system key variables; 2) On Aspects of Operations Strategy where the key variable is Logistics; 3) On Indonesian Navy Posture Aspect where the key variable is Weapon; 4) On Aspect of Threat Perception where the key variable is Maritime Cyber Security.

In this study, Fuzzy Weighting method is used to determine priorities in the development of Smart Defense for the Archipelago's Sea Defense Strategy. After performing calculations using the Fuzzy Weighting method for each criterion, the final weighting results for the main aspects are obtained as follows a) Technological Aspect: 0.27; b) Operational Strategy Aspect: 0.23; c) Indonesian Navy Posture Aspect: 0.26; d) Threat Perceived Aspect: 0.24

The values of these constants will be used in integration with the dynamic system model to produce the final value of the Smart Defense of the Nusantara Sea Defense Strategy.

From The results of the formulation and simulation of the model with a dynamic system approach through several policy scenarios that were developed covering four aspects, namely aspects of technology, aspects of operational strategy, aspects of Indonesian Navy posture and aspects of threat perception, the best scenario analysis results obtained were scenario 3.

Table 20: Scenarios for each aspect and the results of the percentage of smart defense scores.

NO	SCENARIO	SCENARIO RESULTS	PROCENTAGE SMART DEFENSE
1	**Scenario 1:** Aspect Technology	**The Smart Defense score for the Archipelago Sea Defense Strategy increased from 8.16 to 8.33** and the value of the Big Data variable also increased from 0.05 to 0.09 and the integrated system variable from 6.33 to 7.76.	**UP 2.08 %**
2	**Scenario 2:** Aspect Operations Strategy	**Smart Defense score of the Nusantara Sea Defense Strategy from 7.44 to 7.46**, the logistic variable has increased in value from 6.77 to 7.01, command and control from 0.03 to 0.05 then the sea control value from 0.04 to 0.06.	**UP 0.27 %**
3	**Scenario 3:** Aspect TNI AL posture	**The value of the Smart Defense Strategy for the Archipelago's Sea Defense Strategy is 7.42 to 7.73**, Indonesian Navy Posture value from 7.31 to 7.36, Weapon variable from 6.07 to 6.31 and on security variable 0.68 to 0.79.	**UP 4.17 %**
4	**Scenario 4:** Aspect Threat Perception	**The value of Smart Defense for the Nusantara Sea Defense Strategy is 7.18 to 7.06,** The Threat Perception score increased from 8.47 to 8.59, the cyber security variable from 5.63 to 8.06.	**UP 1.67 %**

Source: Authors.

From table 20 above it can be observed that there is a causal relationship that influences each other between the variables in the sub-model from scenario 1 (one) to scenario 4 (four), the value obtained from the smart defense strategy of the archipelago's sea defense with scenario 1 is the value of smart defense in-

creased by 2.08%, scenario 2 increased by 0.27%, scenario 3 increased by 4.17% but in scenario 4 it decreased by 1.67%. In accordance with what was conveyed by experts that organizational capability is the ability of an organization to use its resources (Grant, 2010; Gerry Scholes, and Whittington, 2008). Based on the results of the discussion above, the modeling of the strengths and capabilities of smart defense is basically an effort to build the resources and capabilities of the Indonesian Navy in terms of technology, operational strategy, posture of the Indonesian Navy and considering aspects of current threat perception. In Scenario 1 of the Technology Aspect, by increasing the integrated system variable in the Technology Aspect, it will provide an influential interaction with Big Data variables (IoT, Artificial Intelligence and Machine Learning) and provide value reinforcement for the smart defense of the archipelago's maritime defense strategy. Scenario 2 Aspects of Operations Strategy, by increasing the logistics variable in the Strategic Operations Aspect, in this case, the addition of the Indonesian Navy expenditure budget will have an impact on increasing the Command & control / maritime operation center variable and the value of the sea control variable / sea task force at The marine route of the Indonesian archipelago and followed by increase in the value of the smart defense of the archipelago's maritime defense strategy. Scenario 3 Aspects of Indonesian Navy Posture, increasing the value of the Weapon/Integrated Fleet Weapons System variable by 30% has an impact on the security of a country and automatically increases the value of Indonesian Navy posture which will also have an impact on decreasing the threat perception value. This is not followed by Scenario 4 Aspects of Threat Perception. Maritime security threats, including cyber threats, need to be watched out for, as seen in the decrease in value in scenario 4 (four).

There are some limitations in this research. First, this research is devoted to evaluating the value of each main aspect in smart defense according to experts, the next step is to calculate the weighting value of each main aspect in the smart defense of the archipelago's maritime defense strategy and then proceed to modeling the smart defense to support Indonesian Navy tasks, but not discuss existing threat perception mitigation strategies. Future research can discuss this risk analysis using the same method but with different criteria and alternatives in the future. Second, cyber security and cyber defense where many criteria can be considered which can be discussed in detail in subsequent studies. Third, This study does not discuss threat mitigation strategies as a response to reduce the risk of maritime cyber security threats. Future research can continue this research.

Acknowledgements.

This research is supported by Indonesian Naval Technology College. We also deliver our gratitude to maritime stakeholders who made important contributions to this research.

References.

Anang Setiyawan, J. W. & R. (2018). Strengtening Indonesia's Policy on National Cyber Security To Deal. South East Asia Journal of Contemporary Business, Economics and Law, 15(5), 17–26.

Arif, M., & Kurniawan, Y. (2018). Strategic Culture and Indonesian Maritime Security. Asia and the Pacific Policy Studies, 5(1), 77–89. https://doi.org/10.1002/app5.203.

Azhar, R. (2022). Human Resources Development Efforts in Facing the Society 5.0 Era in Indonesia. Jhss (Journal of Humanities and Social Studies), 6(1), 076–080. https://doi.org/10.-33751/jhss.v6i1.5335.

Batara, H. (2023). Optimizing the Development of Maritime Defense In The Natuna Sea in Realizing Indonesia As The World Maritime Axis. Journal of Industrial Engineering & Management Research, 4(2), 93–101.

Chung, K., Lee, S. Y., Park, S., Park, J., & Han, S. (2014). Development of Information Technology for Smart Defense. Korea, Republic Of.

Cobben, D., Ooms, W., & Roijakkers, N. (2023). Indicators for innovation ecosystem health : A Delphi study. Journal of Business Research, 162(April 2022), 113860. https://doi.org/10.-1016/j.jbusres.2023.113860.

Dipua, A., Harahap, N., Puspitawati, D., Aminuddin, F., & Yudho Prakoso, L. (2021). Sea Defense Strategy the Indonesian Navy in Dealing with the South China Sea Conflict. Italienisch, 11(2), 120–126.

Dipua, A., Hermawan, R., Puspitawati, D., Harahap, N., Rizanny Nurdiansyah, D., & Yudho Prakoso, L. (2020). An Analysis of The South China Sea Conflict: Indonesia's Perspectives, Contexts And Recommendations. Journal Of Archaeology Of Egypt/Egyptology, 17(4), 976–990. https://archives.palarch.nl/index.php/jae/article/view/534.

Dursun, M. (2018). A new integrated fuzzy MCDM approach and its application to wastewater management. International Journal of Intelligent Systems and Applications in Engineering, 1(6), 19–28. https://doi.org/10.18201/ijisae.2018634723.

Flanagan, T., Ashmore, R., Banks, D., & MacInnes, D. (2016). The Delphi method: Methodological issues arising from a study examining factors influencing the publication or non-publication of mental health nursing research. Mental Health Review Journal, 21(2), 85–94. https://doi.org/10.1108/MHRJ-07-2015-0020.

Greiman, V. (2020). Defending the Cyber Sea: Legal Challenges Ahead - ProQuest. Journal of Information Warfare, 19(3), 68–82. https://www.proquest.com/docview/2435722737/A480-26DE74D94390PQ/3?accountid=10286.

Herrera, H., & Kopainsky, B. (2020). Using system dynamics to support a participatory assessment of resilience. Environment Systems and Decisions, 40(3), 342–355. https://doi.org/10-.1007/s10669-020-09760-5.

Huang, J., & Billo, A. (2014). Territorial disputes in the South China sea: Navigating rough waters. Territorial Disputes in the South China Sea: Navigating Rough Waters, 9(2), 1–212. https://doi.org/10.1057/9781137463685.

Jeyarajan, S. (2018). Concept for Knowledge out of Sri Lankan Non-State Sector: Performances of Higher Educational Institutes and Successes of Its Sector. International Journal of Industrial and Manufacturing Engineering, 12(10), 1308–1313.

Lord, C. (2021). The leverage of sea power. Comparative Strategy, 40(2), 194–197. https://doi.org/10.1080/01495933.2021.1880839.

Mustofa, A. Z. (2022). Indonesia's Strategy and Diplomacy in the South China Sea Conflict. Jurnal Pertahanan, 8(3), 414–425.

Olaya, C. (2019). System Dynamics: Engineering Roots of Model Validation. Encyclopedia of Complexity and Systems Science, 1–9. https://doi.org/10.1007/978-3-642-27737-5_544-2.

Payne, K. (2018). Artificial Intelligence: A Revolution in Strategic Affairs? Survival, 60(5), 7–32. https://doi.org/10.1080/00396338.2018.1518374.

Prakoso, L. Y. (2022). State defense strategy through defense public policy analysis in the face of revolution in military affairs. JPPI (Jurnal Penelitian Pendidikan Indonesia), 8(4), 920-925. http://www.jurnal.iicet.org/index.php/jppi/article/view/1963%0Ahttps://www.jurnal.iicet.org/index.php/jppi/article/download/1963/1243.

Raska, M. (2021). The sixth RMA wave: Disruption in Military Affairs? Journal of Strategic Studies, 44(4), 456–479. https://doi.org/10.1080/01402390.2020.1848818.

Rowe, T. D. (1989). Background Paper. Duke Law Journal, 1989(4), 824. https://doi.org/10.2307/1372636.

Russell, G. (2006). Alfred Thayer Mahan and American geopolitics: The conservatism and realism of an imperialist. Geopolitics, 11(1), 119–140. https://doi.org/10.1080/14650040500524137.

Susilo, A. K., Ciptomulyono, U., Putra, I. N., Ahmadi, & Suharyo, O. S. (2019). Navy development strategy to encounter threat of national maritime security using SWOT-fuzzy multi criteria decision making (F-MCDM). Journal of Maritime Research, 16(1), 3–16.

Susilo, A. K., Putra, I. N., Ahmadi, & Suharyo, O. S. (2020). Analysis of national maritime security strategy as an effect of regional development using SWOT, fuzzy multi criteria decision making (FMCDM) and borda. International Journal of Operations and Quantitative Management, 25(3), 153–174.

Tan, Y., Jiao, L., Shuai, C., & Shen, L. (2018). A system dynamics model for simulating urban sustainability performance: A China case study. Journal of Cleaner Production, 199, 1107–1115. https://doi.org/10.1016/j.jclepro.2018.07.154.

Teniwut, W. A., Hamid, S. K., & Makailipessy, M. M. (2019). Selecting top fisheries sub-sector in each sub-district for sustainable development of archipelagic region in Indonesia: A hybrid fuzzy-MCDM approach. Decision Science Letters, 8(4), 393–410. https://doi.org/10.5267/j.dsl.2019.6.001.

Thompson, M. J. (2011). Military Revolutions and Revolutions in Military Affairs: Accurate Descriptions of Change or Intellectual Constructs? Strata, 3, 82–108. https://www.academia.edu/17559441/Michael_J_Thompson_Military_Revolutions_and_Revolutions_in_Military_Affairs_Accurate_Descriptions_of_Change_or_Intellectual_Constructs.

Tomaszewski, L. A., Lacerda, D. P., & Teixeira, R. (2016). Operations strategy for health care services: Analysis of competitive criteria and operational recommendations. Gestao e Producao, 23(2), 381–396. https://doi.org/10.1590/0104-530X-0827-15.

Truong, T. C., Diep, Q. B., & Zelinka, I. (2020). Artificial intelligence in the cyber domain: Offense and defense. Symmetry, 12(3), 1–24. https://doi.org/10.3390/sym12030410.

Zhang, R., & Li, D. (2011). Development of risk assessment model in construction project using fuzzy expert system. ICEMMS 2011 - Proceedings: 2011 2nd IEEE International Conference on Emergency Management and Management Sciences, 866–869. https://doi.org/10.1109/ICEMMS.2011.6015820.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 146–156

ISSN: 1697-4840, www.jmr.unican.es

The Nexus and Implications of Top-level Management Policy, Programme and Strategic Planning Model on Human Resource Performance in the Maritime Industry in Nigeria

Edih, University O.[1,*], Nwafili, Kennedy A.[2], Faghawari, Nyanayon D.[3]

ARTICLE INFO

Article history:
Received 5 Jun 2023;
in revised from 7 Jun 2023;
accepted 28 Aug 2023.

Keywords:
business policy, human resource performance, maritime industry Nigeria, organizational programme, strategic planning model.

ABSTRACT

The research objective is to ascertain how organizational policies, programmes and strategies affect human resource performance in the maritime industry. Primary data were generated using questionnaires and analyzed with multiple regressions statistics at 5% level of significance. The study is anchored on Decision and Human Resource-Based theories. It is revealed that worker's oriented policies, programmes and strategies have positive effects on their performance and overall growth of the organization. The study concludes that business policies, organizational programmes and strategies are veritable and dynamic decision making tools applied by managers to respond to expected and unexpected changes in the maritime business world. It is instructive to Top-level Management/or leaders to study every environmental scenario (competitive indices or externalities, worker's attitude, customers disposition, etc) and formulate appropriate policies, programmes and strategies that will produce optimal and sustainable human resource performance. Workers should be encouraged with motivational policies and programmes supported by welfare schemes to improve commitment, efficiency, productivity, and profitable performance, especially in the maritime sector.

1. Introduction.

Employees are considered as critical success factors (Omisore and Okufu, 2014) judging from the fact that technologies cannot perform a given task in isolation without being operated on or giving instructions (garbage in garbage out formula) in every organization or working environment. They (workers) are pivotal to organizational management and performance (Salami et al., 2013)**,** and a veritable, indispensable asset to growth and development of the organization (Edih, 2021). It is the utmost need to boost worker's morale, commitment and triple productivity that aroused management thinkers to develop organizational theories on motivation and related concerns (Herzberg two factor theories, theory Y & X of McGregor, Maslow's hierarchy of needs). Undoubtedly, every organization, profit or non-profit, is run by man (both employers and employees supported by ICTs in modern times). The maritime industry has become a sustainable pillar in revenue generation to the Nigerian economy in recent years (Osadume and Edih, 2021), as catalyst for economic growth and gateway to international trade and global relationships (Omoke et al., 2019; Edih et al., 2022a). This has necessitated the need to look at policies and programmes, as well as develop strategies towards improving its (or worker's) performance in a competitive business terrain.

Achieving optimal performance, and/or growth, whether at organizational or individual level is hinged on several connected factors. In similar instances, human resource or worker's performance is dependent on some motivating and propelling socio-cultural ingredients (Heinz et al., 2003; Ogbor, 2019). Socio-cultural factors are subsumed in the context of organizational structure and culture (policies, programmes, plans or strategic

[1]Nigeria Maritime University, Okerenkoko.
[2]Dennis Osadebay University, Asaba.
[3]Nigeria Maritime University, Okerenkoko.
[*]Corresponding author: Edih University. E-mail Address: oweilade123uni@gmail.com.

planning, procedures, managerial relation, e.t.c.). Policies, programmes and strategies are formulated by top-level management to achieve target goals and objectives for a specified period of time (Eromafuru, 2016; Ogbor, 2019). Some categories of goals or objectives are termed short-term while others are called long-term. How policies, programmes and strategies are carried out vary from one organization to the other and how they influence the human asset or personnel depend on various decision variables (i.e., worker's welfare, management disposition, environmental factors, e.t.c.), (Oyoo, 2014).

Behzad et al., (2020) identified political behaviours, expertise in negotiations, communicative technologies, relations with extra-organizational agents, effectiveness of regulations and organization as factors that influence the formulation of strategies and policies. More so, since society is complex and dynamic, organizations are compelled to respond to unpredictable changes in order to be competitive and remain afloat. Organizations are bound to adopt positive strategic changes to survive the competitive business environment since dynamic and strategic planning models are the backbone of organizations in today's changing world (Nasratullah, 2022). Arguably, viability and sustainability of business organization, to a large extent, is according to the degree of dynamism and sophistication of its policies, programmes and strategies in reaction to changes in the business environment.

In Jayawarna and Dissanayake (2019), strategic planning (SP) is integral to organizational performance, growth and development. Studies on SP have shown mixed effects (i.e.,positive and negative) and such strategic models are usually affected by both internal and external factors that may limit and propel worker's performance or organizational growth. Conceptually, Jayawarna and Dissanayake (2019) split "strategic planning" into two; strategy and planning. Strategy is derived from a Greek term "strategos" meaning the duties of a general or manager (Eromafuru, 2016 ; Mohamed, 2010), while planning explains the process of assembling resources and putting them into effective and efficient uses towards achieving the objectives of the organization (Khan and Khalique, 2014). SP is a detailed activity documented to enhance productivity of an organization.

Strategic planning model has a number of rewards such as coordination of business units, reviews performance and progress, identifies and exploits marketing opportunities, energizes communication channels, and motivates the human resource (Aldehayyat and Twaissi, 2011).Strategic planning models are diverse,- human resource strategy, ICTs strategy, financial strategy, automation strategy, e.t.c. The effects of globalization inform the adoption of ICTs and automation strategies in modern organizations. The benefits of robotic process automation (RPA), which is expanding into intelligence automation (IA) are enormous. Enterprise-Wide Automation (EWA) creates five times more business value. IA is one of the most impactful transformation levels in organizations, because it helps to recreate or re-think how work ought to be done and add to the business value chain in new dimensions. The strategic positioning of intelligence automation is integral to business advantage (SS&C Blueprism, 2023).

Business performance has been improved by 80% in organizations with programme and strategic plan better than enterprises without documented strategic planning model (Karel et al., 2013). Positive correlation was found between strategic planning or programme and performance of SMEs and the dimensions of strategic planning are ; environmental scanning, business and vision, formal strategy plan, evaluation and control, informing sources, strategy implementation incentives, employee's participation and time horizons (Sandra et al., 2014 ; Wijetunge and Pushpakumari, 2014). In Wijetunge and PushpaKumari (2014), constructs used to proxy or measure the impact of strategic planning are; vision, mission, goals and objectives, internal and external analyses, strategy formulation, implementation, control and review, while business or organizational performance was measured by annual sales and profits, number of employees, market shares and investments in the business.

Organizational theory emphasizes capacities and strategic planning procedures, while contingency theory advocates " the no best way of organizing and leading an institution". That means, actions taken in the organization are contingent upon the internal and external factors. Strategic planning, programme and organizational performance are dependent on both endogenous and exogenous (environmental) factors (Jayawarna and Dissanayake, 2019; Mohamed, 2010).

Organizational performance measurement may as well be classified into short-term and long-term performance. Financial performance is tied to long-term plan and growth in terms of the size and assets are influenced by strategic planning model, policy and programme (Baker and Thompson, 1986 ; Sheehan, 1975 both cited in Jayawarna and Dissanayake, 2019). In other studies, there exists a positive connection between strategic planning and financial performance, and that strategic planning tools include ; mission statement, competitor's analysis, long-term goals, annual goals, short-term action plan and ongoing evaluation (Aldehayyat and Twaissi, 2011;Baker, 2003; Jayawarna and Dissanayake, 2019; Philips, 2000). The literature review in Jayawarna and Dissanayake (2019) suggest that strategic planning has positive performance effects as demonstrated in (Mintzberg, 1973; Wood and LaForge,1976 ; Sapp and Seiler, 1981). Planning is a key lever for transformative change in an industry (Flamholtz and Kurland, 2006), which helps in evaluating and identifying long-term goals, objectives, motivates and organizes workforce, allocate scarce resources and ensure control and monitor actual performance in comparison with standard performance/target (Sophia and Owuor, 2015).

From the foregoing, literature has mixed results or reactions on the importance or effect of plan or strategic planning on organizational performance (Jayawarna and Disanayake, 2019; Mohammed and John, 2012; Rudd et al., 2008). It has also demonstrated the relationship between strategic planning and financial performance (Jayawarna and Dissanayake, 2019). More so, plethora of investigations on strategic planning abound, (Khan and Khalique, 2014 ; Mohammed, 2010 ; Mohammed et al., 2020 ; Moody,n.d ; Nasratullah, 2016 ; Ogbor, 2019; Ogonji, 2014), but non on the subsisting nexus between policies, programmes and strategic planning vis-a-vis human resource per-

formance in the maritime industry. Studies on the specific or combined effects of business policies, programmes and strategic planning models on human resource performance in a dynamic environment are lacking. It is this gap that the study intends to cover.

2. Review of Related Literature.

2.1. Conceptual Review.

Under this section, a discourse on strategy/strategic planning model and the nexus connecting policy, programme, strategic planning model and human resource performance, the maritime industry in Nigeria were examined.

2.1.1. Critical discourse on Strategy and Strategic Planning Process.

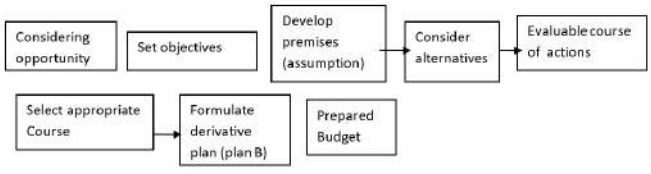
Strategy planning process (SPP) is a powerful tool and guidelines at the disposal of top management and leaders (Shu-Hsiang, et al., 2018), which serves as a toolkit for mapping out strategies. As a key element for successful management of an organization, SPP provides direction for managers/leaders (Paris, 2003). Planning, policy, programme as well as strategic plan envision the future, and develop realistic plan of action and they are necessary components for making decisions in every organization, both in profit and non- profit enterprises (Schmidt and Laycock, n.d, as cited in Shu-Hsiang, et al., 2018). Strategic planning or plan is the backbone of strategic management, helps in understanding planning process or practices, corporate culture, decision making process, organizational structure and performance (Mohammad and John, 2012). Strategy is the product, procedures and methods arrived at in a strategic planning process towards attaining the target objectives or goals of the firm. The formulation of Strategic Planning Model (SPM) is influenced by many and diverse factors, making organizations to design its specific planning model. The SPP model designed by Kotler and Murphy (Shu-Hsiang et al., 2018) has the following components; environmental analysis, resource analysis, goal formulation, strategy formulation, organization design, and system design.

Similarly, the SPP model developed by the Research Foundation at the State University of New York, had seven coordinated steps; gathering and analyzing information, identifying critical issues/problems, developing strategic vision, reviewing the mission statement, developing strategic goals, formulating strategy for each goal, and developing annual objectives. The Lerner SPP model explains the concept of strategic planning using the following components ; mission/vision, strategic issues (i.e., gaps analysis , benchmarking, environmental scanning, and SWOT analysis), intended/emergent strategies, ongoing strategic programme, and strategic learning/thinking (Shu-Hsiang et al.,2018). Strategies are designed to suit the peculiarities in terms of problems, issues, environmental factors, mission and vision of the organization. The variance in composition of SPP models were deliberately captured by the formulators, portraying the dynamism associated with strategies. Shu-Hsiang developed a seemingly simple conceptual SPP model comprising the following six components; envisioning, social situational analysis, strategy formulation, taking action, and evaluation, and sustenance. Thus, strategic planning is a complex, dynamic and time - intensive process whose objectives cannot be achieved without a firm, thoughtful and realistic plan for the future (Shu-Hsiang et al., 2018).

Strategic planning is a channel for internal and external communication (Jarzkowski, 2010) and the determination of the basic long-term goals and objectives of an enterprise (Barbosa and Romeo, 2016). It is the setting of vision, objectives, and methods of achieving the goals, mission and vision (Strickland, 2003) and the document that promotes interactions between staff at the workplace (Spee and Jarzkowski, 2011). The process that defines strategies and provides direction for making decisions is known as strategic planning (Kathleen et al., n.d). Strategic planning is critical to institutions of higher education because it gives stakeholders opportunities to agree and build commitment (Allison and Kaye, 2005; Kathleen et al., n.d). As a formal process, SP identifies and maximizes optimal results (Rowley and Sherman, 2001) and represents a leadership tool for giving direction (Kathleen, et al., n.d). Bryson (2011) sees SP as a focused, disciplined, and fundamental decision making process that shapes the culture of the organization. The strategy of an enterprise or institution reflects its mission and vision.

Ordinarily, planning entails some practical steps such as, looking out for opportunities, setting objectives, developing premises (assumptions), considering alternatives courses, evaluating such courses, selecting appropriate course of action, formulating derivatives (i.e., plan B), and preparing a budget.

Figure 1: The Planning Process.



Source: Author.

Heinz et al., (2011) contends that strategies and policies are necessary for effective management of an enterprise. Strategies are executed through action plan known as tactics. Strategies, programmes and policies are designed to direct overall operations in aspect of organizational growth, financial management, personnel management, public relationships, promotion of products and services, and general marketing. Strategic planning process (SPP) is central in making decisions in the organization. Ogbor (2019) explains strategy to mean a game plan, chosen to achieve organizational objectives, gain customer's trust, attain competitive advantage, and acquire a market position, among other factors. Therefore, Strategy can represent a unified and integrated plan, dynamic with long-term perspective usually formulated by top-level management. Ogbor (2019) tried to distinguish policy from strategy. According to him, strategy is a plan of action while policy is a principle of

action.Strategy is more dynamic but policy is likely uniform in nature. Policy is a set of common rules and regulations which serves as the basis for daily operations. Policies are inside-out driven and strategies are out-side driven. Policies and strategies are both formulated at top-level management.

2.1.2. The Nexus between Policy, Programme and Strategy.

Heinz et al.,(2011) defines planning as "the selection of missions , objectives and actions to achieve them". Planning requires decision making, choosing a course of action, usually among alternatives. The authors classified plans into; mission or purpose, objectives or goals, strategies, policies, procedures, rules, programmes and budgets. The trio concepts- policy, programme and strategy are types of plan or ways of planning. Policy, programme and strategy are intertwined in usage and application. There may be a thin difference but intended to achieve the target objectives and goals of the organization. Policy is a plan that demonstrates general statement or understanding that guides logical thinking in decision making. It defines areas where decisions are to be made and assists in deciding knotty issues and resolving problems. Programme is a complex goal, policy, procedure, rules, task, steps to be taken, resources to be employed and other necessary elements to execute a chosen course of duty.

Policy can be seen as part of a programme while policy is a broad guide for a given project or programme. Programme is always backed by budgets and may be grouped into major and minor in terms of budget, size and duration. Strategy connotes "the determination of the basic long-term objectives of an enterprise". It involves the adoption of courses of action and allocation of resources appropriate for attaining set standards (Heinz et al., 2011). Eromafuru (2019) sees the programme as a detailed course of action which embodies missions and objectives of an organization. It encompasses policy, procedure, or rules employed in achieving organizational goals. According to Ogbor (2019), policy defines the limit within which decisions are considered, and it the responsibility of top-level management to design the policy of an organization. As internal management law, it may be written or oral. It guides the discretion of low-level management in dealing with daily issues and problems. The popular "whistle blowing policy" adopted by many countries including Nigeria is a good example of government policy. There may be differences between government policy and business policy, however, both are tools for making decisions (governance and investments, etc.).

2.1.3. The Maritime Industry in Nigeria.

Globally, the maritime industry deals with the transportation of goods and people by sea and rendering services that facilitate maritime business. The industry is largely synonymous with waterborne transport or carriage by sea which is different from carriage by land and air. Essentially, the industry uses container ships, oil tankers, cruise ships, and passenger's ferries as well as small vessels for fishing adventures. Notably, maritime transportation is connected to ports and their operations (loading and off-loading of cargo at the terminals, jetties, management of the human resource, etc). The industry is apportioned into segments such as; cruise and ferries, offshore work, ports, cargo shipping, naval ships, fishing and ecology, etc. The most appreciated sections in the industry are; maritime shipping, ports, shipbuilding, ship supply, marine engineering, offshore wind energy, and maritime research and development (MRD). According to Edih, et al., (2022b), maritime business is partly anchored on seaports and regulated by international laws,(i.e., treaties, conventions). Ports have been seen as the gateway to international trade, economic growth and global network (Inah and Elijah, 2018). Therefore, maritime business can partly be explained to mean shipping and port operations. Elem (2008) identifies operations taking place in ports to include ; dry docking, coastal shipping services, trawler services, building terminal and jetty infrastructures, offshore construction, and fabrication, etc. Other activities are; barge and house boat, dredging services, tourism, pilotage and towage, supplying fuel to mooring vessels (Edih et al., 2022b; Peretomode, 2014).

The maritime sector in Nigeria is controlled and regulated by Nigeria Ports Authority (NPA) and Nigeria Maritime Administration and Safety Agency (NIMASA). NPA was established in 1954 to oversee the operations in the sector and NIMASA came into force in 2006 to ensure effective and efficient service delivery, growth and development of the industry (Peremode, 2014). We hope there is no conflict of functions between the two sister agencies. Based on the policies of public private partnership (PPP), economic liberalization and expansion (ELE), and trade openness, the federal government(FG) made arrangements on concession of port's terminals to private companies to create investment opportunities and enhance competitiveness in the industry. Such registered private companies with Corporate Affairs Commission (CAC) and doing maritime business are (Corporate Affairs Commission, Abuja, Nigeria, CAC, 2023);

1. Aquashield Oil & Marine Services Ltd Port Harcourt Nigeria.
2. Rock Marine Services Ltd Akwa Ibom Nigeria.
3. Quality Marine Services Ltd Lagos Nigeria.
4. Blueseas Marine Services Ltd, Lagos, Nigeria.
5. Tamrose Ventures Ltd, Port Harcourt, Nigeria.
6. Pobeto Ventures Ltd, Warri, Nigeria.
7. Coastland Energy Logistics Ltd, Lagos, Nigeria.
8. Craft Offshore International Ltd, Lagos, Nigeria.
9. Damas Oil and Marine Services Ltd, Port Harcourt.
10. Deino Maritime Services Ltd, Lagos Nigeria.
11. Duncan Maritime Ventures Nig Ltd, Lagos Nigeria.
12. Fymak Marine and Oil Services Nig Ltd, Lagos Nigeria.
13. Homeland Integrated Offshore Services Ltd, Lagos Nigeria.
14. Indo Marine Nigeria Ltd, Lagos, Nigeria.
15. Japaul Plc, Lagos, Nigeria.
16. Oarsmanns Maritime Services Ltd, Port Harcourt Nigeria.
17. Seafloat Marine Services Ltd, Port Harcourt Nigeria.

18. Silvetti Marine Survey Ltd, Warri Nigeria.
19. Zircron Marine Ltd, Lagos Nigeria.
20. Fedim Marine Services Nig Ltd, Lagos Nigeria.
21. Mid Maritime Services Nig Ltd, Lagos Nigeria.
22. Nimpam Marine Services Ltd , Port Harcourt Nigeria.
23. Richmond Marine & Offshore Logistics Ltd Lagos Nigeria.
24. Indo Marine Nigeria Ltd Lagos Nigeria.
25. Basilman Group of Companies Nigeria Ltd, Port Harcourt Nigeria.

It is crystal clear that the various business segments in the maritime sectors are carried out by the employers and employees (human resource) who are rather indispensable to proper functioning of the industry (Edih, 2021; Omisore and Okufu, 2014). Therefore, to enhance smooth running, and improve organization and performance, the need to formulate policies and strategies (in recruitment, selection, training, placement, motivation, rewards, productivity, etc) is very important in the face of a dynamic and competitive business environment.

3. Empirical Studies.

The following previous studies were reviewed;

In Nasratullah (2022), dimensions such as, mission and vision statements, SWOT analysis, cooperation agreements, R&D, and database were used to measure strategic planning, while inclination to cooperation, experience exchange, rewards, market share, profit, growth and innovation measured performance. The study affirms a positive performance effects. Strategic planning has positive impact on organizational growth (Hani, 2021; Okolocha, 2020), a substantial positive association between innovation and strategic goals (Donkor et al., 2018 ; Efendioglu and Karabulut, 2010 ; Mohamed, 2010), strategic human resource planning and performance (Murriithi et al., 2018). There also exist a positive relationship between innovation and strategic planning, because innovation culture is a key success factor for creating new products and services, new approaches to resolving issues, enhancing competitive advantage and improved performance (Aziz and Samad, 2016 ; Mohammed et al., 2020).

Gumel (2019) took a qualitative approach to examine the impact of strategic planning on growth of small businesses and its results could not guarantee any significant relationship between planning and transitional growth, but inferred that, planning process and the communication of such influences customer's loyalty, improve sales and business growth. Strategic planning affects financial performance of small businesses (Delmar and Shane, 2003 as cited in Gumel, 2019), human resource recruitment and management (Davila and Foster, 2007) and secures venture capital (Rue and Ibrahim as cited in Gumel, 2019).

According to Ogonji (2014), the strategic planning model is developed in line with the peculiar needs of the organization, meaning, SPM for firm A is never the same with firm B. SP is a vital component of organizational management kit. It helps to identify strengths and weaknesses and provides a roadmap for leaders (Moody, n.d ;). The maximization of objectives and goals rests on strategies (James, 2009). Oyoo (2014) identified some determinants of SP, which include, leadership, commitment, socio-cultural climate, trends, past events and available resources.

Several organizations are responding to the big question of "opportunities and threats" through three levels of strategic plans - organizational, pragmatic and operational strategies (Joe, 2015). Other strategic planning dimensions include, conventional, issues-based, organic, real-time, and alignment models. Each model is designed to fit the situational problem, mission and vision, objectives of the organization. Effective application of strategies assist in identifying long-term goals, organize productive workforce, allocate scarce resources, necessitates growth and monitors performance(Odongo and Dutche, 2015). Technological advancements are seen to compel firms to find ways to be competitive and remain in business and one of such ways is designing suitable strategies (Jovica et al., 2016; Vargo and Servile , 2011).

Kingsley (2018) describes policy as a basic managerial instrument used to enhance employee's work quality, engagement and enhances administration of an enterprise. It is argued that workers become more engaged and productive, when involved in policy formulation. Employees are motivated through their contributions to organizational policies and this fosters competitive advantage (Fopohunda, 2013; Lasrado, et al., 2016, both cited in Kingsley, 2018). Employee's participation in developing policies has led to work balance and higher performance (Maxwell, 2005; Walter, 2015, both cited in Kingsley, 2018). Thorough implementation of organizational policies lies on worker's commitment (Danaeifar et al., 2016). It is affirm that change is a major part of human life (Lucie, 2013) and policy change represents the incremental shift in existing structures and/or simply put, innovations (Bennett and Howlett, 1992, as cited in Lucie, 2013). Policy and policy change were explored using several theories, such as, path dependence, advocacy coalition framework, policy learning diffusion, punctuated equilibrium, institutional change, multi-level governance, policy networks, amongst others. Policy has become one the basic tools (for example, monetary and fiscal policies, naira redesign policy, e.t.c.) used to stabilize and develop an economy. It helps to integrate the various departments (personnel, Finance, marketing, e.t.c) in the organization (Sunday and Idodo, 2016).

4. Theoretical Studies.

The study relied on Decision and Human Resource-Based Theories because of their relevance to planning or decision making process towards improving organizational performance and sustenance.

4.1. Decision Theory.

Decision making has become one of the interdisciplinary sciences (Steve, 1990). According to the designation of Suppes (1961 as cited in Steve, 1990), the major sciences involve in decision theory (i.e., then) on the basis of normative and descriptive theories are shown in table 1 below;

Table 1: The decision sciences.

	Individual designs	Group decisions
Normative theory	Classical economics Statistics decision theory Moral philosophy	Game theory welfare economics political theory
Descriptive theory	Experimental decision learning theory survey studies of voting behaviors	Social psychology Political sciences

Source: Suppes 1961 (cited in Steve, 1990, P.5).

Decision theory is concerned about the methods of determining the optimal course of action after considering available alternatives. It is the analytical and systematic approach towards making decisions. Decisions may be good when based on reasoning, available alternatives, and quantitative analysis, but maybe bad when the reverse happens. In a nutshell, decision theory is all about decision or understanding the decision making process (Steve, 2005). There are different ways of arriving at a decision or theorizing about decisions. Decisions are made by individuals, private bodies and government institutions on a daily basis. Decision making process has been grouped into normative and descriptive approaches. Decisions that are basically made on the basis of norm or rationality or the thought on how a decision should be made is known as normative theory of decision and how decisions are actually made refers to descriptive theory. There are prerequisites or procedures or factors for a rational decision making or norms of rationality. Decision theory provides methods, approaches and diagnosis for managers and/or leaders to achieve business growth, worker's optimal performance and maximize profits (Steve, 2005).

According to Dewey (1978, as cited in Steve, 2005), problems may be solved in the following succession; the felt difficulty, defining the characteristics of the difficulty, suggest possible solutions, evaluate the solutions, do further observation and experimentation before accepting or rejecting a position. These steps were modified by Simon's work (Steve, 2005) to three major stages ; find occasion for making a decision, find courses of action, and choose a course of action. These three phases can be expressed as, intelligence stage, design stage and choice stage. In Brim et al., (1962), the decision making process is divided into five consecutive steps; identify the problem, obtain relevant data, e.t.c. However, some scholars disagreed or criticized the sequential format of processing decision(s). They advocate a non-sequential model for making decisions and a key proponent is Mintzberg et al., (1976 as cited in Steve, 2005). Mintzberg et al., (1976) provided three distinct, but not sequential approaches; identification, development and selection.

What we know is that certain parameters are considered and evaluated before taking a position or a course of action. Decision theory tries to capture problem(s) that manifest characteristics such as; alternatives to choose from, showing future conditions that may affect any choice made, and have a known payoff for the alternatives. Decisions are also made in diverse environments- environments with certainty of parameters, with risk because of probable outcomes and with uncertainty due to the likelihood that future events are not known or cannot be assessed. In modern management, decision making steps include; identifying the problem, specify objectives and criteria for the solutions, develop suitable alternatives, analyze and compare alternatives, select the best alternative, implement the solution and monitor results (Eromafuru, 2016 ; Heinz et al., 2003; Ogbor, 2016). Therefore, the decision making process is not far from the planning process. Arguably, decision is the product of a plan which maybe policy, programme or strategy while planning is a deliberate decision process to have a plan for achieving desired goals. A decision is a plan, while a plan is a decision, and both are two-side of a coin.

4.2. Human Resource Based Theory.

The indispensability of the human capital in implementing the activities of an organization is the epicenter of the human resource-based theory (Charlotte and Jan de, 1999).Workers or employees are the most valuable resource of the organization and human resource management is pivotal to the effectiveness and efficiency of the human resource (Eromafuru, 2016). Human resource management practices are very germane in hiring, training and developing the human capital in an organization. Some companies have invested in technologies to boost the productive capacity of their workers while others deployed motivational programmes to increase employee's interest in the job and enhance performance.

HRB theory emphasizes the importance of various stakeholders who are part of the "dominant coalition" (i.e, employers, employees, shareholders, customers, competitors, government, e.t.c.), of an organization. The values and attitudes of the dominant coalition decide the long-term objectives and ways of managing the workers. The HRB theory also considers the constraints (i.e, products, organization and social dimensions) that limit the room for manoeuvring (Charlotte and Jan de, 1999).

Paauwe (1998) designed a conceptual model on how human resources are to be deployed, how some factors affect their deployment and the possible outcomes. Walker (1978) discovered a linkage between human resource planning and strategic planning and Wright et al., (2001) agreed to the convergence between strategies and strategic human resources management (SHRM). The connection between business strategy and performance was explored in Devana et al., (1984) and Wright et al., (2001) conclude that the resource based view (RBV) is instrumental to the development of HR practices. Firms are advised to leverage on the human resources management practices to enhance their competitiveness (Lado and Wilson, 1994).

5. Methods and Materials.

The study used primary data generated through questionnaires. The questionnaire comprises 15 research questions drawn from the three constructs forming the independent variables. A set of questionnaires was distributed to 400 respondents which formed the sample of the investigation. The sample is representative of the population (staff) of the 15 selected private maritime companies, NPA and NIMASA(section 2.1.3). Each company was allotted 20 set of research questions on an equal

proportion basis while NPA and NIMASA were given 50 each. The options for answers were designed according to four points Likert summated scale (i.e, strongly agree, SA; Agree, A; Disagree, DA; Strongly Disagree, SD). However, three hundred and forty-five questionnaires were retrieved (i.e, 86.25% was returned). The data were analysed using correlation and multiple regressions analyses. We employed multiple regressions because it gives room for the addition of more variables. It accommodates the testing of multiple variables in a single analysis without necessarily compromising results for each specific variable. The effect of the independent variables on the dependent variable was tested at 5% level of significance.

Table 2: Participant's demographic information.

Demographic Variables	category	frequency (N= 345)	%
Gender	male	150	43.47
	female	195	56.53
Qualifications	graduates	280	81.15
	Post graduate	65	18.84
Experience	0-5years	200	57.97
	5-10years	145	42.03

Source: Authors.

5.1. *Definition of Variables.*

The independent variables are grouped into three according to the three constructs or concepts and the formulated hypotheses. They are business policy, organizational programme and strategic planning model and the dependent variable is human resource performance which will eventually culminate into overall organizational performance.

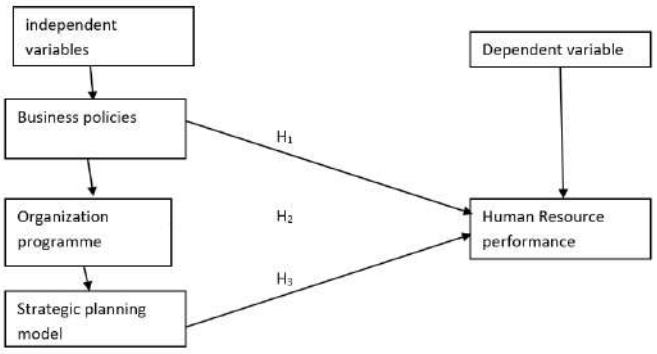
Business policy (BPY) entails the principle, guidelines and direction which the courses of action will take. Such policy is derived from the vision and mission, goals and objectives of the organization. Examples are; gender inclusion policy, recruitment policy, public relations policy, policy on workers motivation, e.t.c.

Organizational programme (OPM) is the project embarked on or to be embarked on in an organization. Such programmes or projects are supported by approved annual or supplementary budgets. Examples are, worker's training, study leave, setting up a new plant, or new branch, purchase of machineries, e.t.c.

Strategic planning model (SPM) represents the tactical or step by step process(es) followed by top management in formulating a strategy. Strategic planning is geared towards achieving long-term goals or objectives of the organization.

Human resource performance (HRP) is the invaluable performance of workers in the organization (, i.e, the banking industry in Nigeria). Human resource is also called human capital, personnel, workers and staff. Performance is measured in terms of punctuality, commitment, productivity (volume of production, sales, e.t.c.). HRP is the dependent variable.

Figure 2: Study framework.



Source: Authors, 2023.

5.2. *Model Specification.*

On a general note, multiple regressions analysis model or equation is represented mathematically, (Vincent et al., 2010) as;

$$Y = a + b_1(X_1) + ... + b_n(X_n) + e \quad (1)$$

Where, Y; is the dependent variable.

X_1-X_n; are the independent variables.

b_1-b_n; are the coefficients.

a; is the constant.

e; is the error term due to the imperfection of the model or stochastic disturbance associated with construction of models.

Based on the above, the functional expression of the variables in the study is;

$$HRP = f(BPY, OPM, SPM) \quad (2)$$

After undergoing, econometric transformation or linearization it will become,

$$hrpt = at + b1(bpy)t + b2(opm)t + b3(spm)t + et \quad (3)$$

Where, hrpt; is human resource performance at a given trend or period.

bpyt; is business policy for a given time.

opmt; is the organizational programme for the period.

spmt; is the strategic planning model for a given trend.

t; is the stipulation time or trend.

5.3. *A Priori Expectation.*

The result should show a positive and significant relationship between the independent variables (business policy, organizational programme and strategic planning model) and the dependent variable (human resource performance).

6. Results and Discussion of Findings.

This section is divided into two subgroups, results and discussion of findings.

6.1. Results.

Results from the correlation and multiple regressions analyses are presented in tables 3-4 as shown below;

Table 3: Correlation analysis of the variables.

Constructs	BPY	OPM	SPM	HRP
BYP	1.0000			
OPM	0.4575	1.0000		
SPM	0.5372	0.4261	1.0000	
HRP	0.5115	0.6242	0.4444	1.0000

Source: Authors, SPSS compilation, 2023. p¡0.01.

The correlation analysis of variables reveals a positive correlation among the variables used. This shows that, business policy (bpy) has a positive association with organizational programme (opm) and strategic planning model (spm) and human resource performance (hrp), (r = 0.4575, 0.5372, & 0.5119; p<0.01) respectively, and human resource performance (hrp) has a positive relationship with bpy, opm, and spm (r= 0.5119, 0.6242 & 0.4444; p<0.01) respectively.

Table 4: Regressions analysis of the variables.

Source	ss	df	ms	N°. of obs = 345		
Model 1	144.6487	3	48.2162	F (3, 246) = 224.19		
Residual	52.9072	246	0. 2151	prob > F = 0.0000		
Total	197.5559	249	0. 7934	r-squared= 07322		
				Root MS = 0.4637		
Cad	Coef	std.Err	T	P>/t/	95% conf.	interval
Bpy	0.1100	0.0387	2.84	0.005	0.0336	0.1864
Opm	0.1265	0.0374	3.39	0.001	0.0530	0.2001
Spm	0.7018	0.3987	17.60	0.000	0.6233	0.7803
-cons	0.2931	0.1519	1.93	0.055	0.0061	0.5922

Source: Authors, SPSS compilation, 2023.

6.2. Discussions of Findings.

The result in Table 4 indicates the contributions of each independent variable on the singular dependent variable. Statistically, the effect of business policy (bpy) on human resource performance (hrp) is positive and significant, (i.e, Coef.= 0.11, p = 0.005<0.05);"opm" has positive and significant effect on "hrp", (i.e, Coef.=0.1265, p= 0.001< 0.05); and "spm" shows positive and significant performance effect, (i.e, Coef.,= 0.7018, p= 0.000<0.05). It is appropriate to conclude that policies, programmes and strategic planning models influence human resource performance in the maritime industry in Nigeria.

The three p-values of the independent variables are less than 0.05,(i.e, 5% level of significance), which necessitate the decision to reject the null hypotheses and accept the affirmative. More so, the Adj.-square of the model is 0.7289, meaning that, 72.89% change in the human resource performance is attributable to top-level management policy, programme and strategic planning model.

These findings are corroborated by previous studies.

Studies on Policy versus Performance.

Accordingly, there exist a positive and significant relationship between business policies and performance (Danaeifar et al., 2016; Jayawarna and Dissanayake, 2019), and policies enhance competitiveness (Kingsley, 2018; Sunday and Idodo, 2016).

Studies on Organizational programme versus Human resource growth.

Few studies affirm that organizational programmes affect worker's performance. Programmes such as training (and study leave) refresh/boost the morale, capacities and capabilities of workers for improved performance(Sandra et al., 2014; Wijetunge and PushpaKumari, 2014).

Strategic planning model versus Corporate culture / Performance.

The studies of Nasratullah (2022), Okolocha (2020), and Khan and Khalique (2014) support the position that strategic planning models or strategies have positive performance effects, affect efficient allocation of resources and the backbone of corporate culture (Mohamed and John, 2012). Strategic recruitment plan or policy coordinates the hiring of competent hands.

7. Conclusion and Recommendations.

Theoretically, the nexus between policy, programme and strategy was considered on one part and empirically, the specific effects of the trio-concept on human resource performance was tested on the second part. The study affirms the intricate connection between the three conceptual variables in terms of plans or process of developing plans. Though, they represent different categories of planning in the organization. More so, it is one of the basic responsibilities of top-level management to design appropriate policies, programmes and strategic planning models for growth and development of the organization. It is also enunciated that, business policies, programmes and strategies ought not to be static since society is bound to changes and change is the only constant in the global economy. It is evident that competitiveness, and sustainability of enterprises in modern times largely depend on viable, and firm but dynamic business policies, programmes and strategies.

Strategic planning and programmes are driven within the umbrella policy, mission and vision statements of the organization and such policies, programmes and strategies vary from one institution to another. It is ideal to state the indispensable values and contributions of the human asset to the survival of any organization is beyond quantification, as buttressed by the Human Resource Based and Decision Theories as well as previous studies. Undoubtedly, the policies, programmes or strategies formulated by top management are implemented by personnel of the organization. It therefore, behooves or is incumbent on top management to design and establish worker's oriented policies and programmes as well as strategies. On the second hand, empirical results showed that business policies,

organizational programmes and strategic planning models have positive and significant relationship or effects on worker's commitment, motivation and performance in the maritime industry. Since, policies, programmes and strategies are plans and decision making tools at the disposal of top-level management, they should be fine-tuned to improve overall human resource performance.

Acknowledgements.

We are glad for the awesome cooperation received from the staff of NPA, NIMASA and the private maritime organizations. They responded to the questionnaires with utmost good faith. Also, we are declaring that the study was not sponsored and there is no conflict of interest.

References.

Aldehayyat, J. S., and Twaissi, N. (2011). Strategic planning and corporate performance relationship in small business firms: evidence from a middle East Country context. International Journal of Business and Management, Vol. 6 No. 8, pp. 255-263.

Aziz, N.N.A.,and Samad, S. (2016). Innovation and competitive advantage: moderating effects of firms age in foods manufacturing SMEs in Malaysia. Procedia Economics and Finance, Vol. 35, pp. 256-266. https:/doi.org/10.1016/s2212-5671(16)00032-0

Baker, G. A. (2003). Strategic planning and financial performance in the food processing sector. Review of Agricultural Economics, Vol. 25 No.2, pp. 470-482.

Barbosa, F., and Romeo, F. (2016). The links between innovation, strategy and internalization processes : a comprehensive literature review. Academic Conference, pp. 904-912. Jyvaskyla: Finland : Publishing International Limited.

Behzad, S., Reza, N. B., and Karamullah, D. (2020). Factors affecting the strategic planning in local organizations for designing a structural model. Revista Ciencia UNEMI, Vol. 13 No.34, pp.1-15.

Brim, Orville G. et al., (1962). Personality and decision processes, studies in the social psychology of thinking, Stanford.

Deloitte(2023). Chief strategy officer survey. Available at; www.deloitte.com/us/chiefstrategyofficer.

Charlotte, K., and Jan de, K. (1999). A human based theory of the small firm. Research Report, 9906/E.

Devana, M.A., Fombrum, C. J., and Tichy, N.M.(1984). A framework for strategic human resource management. Human resource management (chapt.3 pp. 33-51). New York : Wiley.

Donkor, Kwarteng and Aidoo (2018). The moderating role of innovation capability and strategic goals in the financial performance of small and medium enterprises in Ghana.

Edih, U. O., Igemohia, F., and Faghawari, D. N. (2022b). Prospects and challenges of maritime business in Nigeria. Direct Research Journal of Management and Strategic Studies, Vol. 3 No. 2 pp.5-13. Doi: https://doi.org//10.26765/DRJMSS-20967731.

Edih, U. O., Igemohia, F., and Faghawari, N. (2022a). The effect of optimal port operations on global maritime transportation : a study of selected ports in Nigeria. Journal of Money and Business, Vol.2 No.2 Pp. 173-185 Doi : https://doi.org/10.1108/-JMB-07-2022-0037.

Edih, U. O. (2021). Recruitment strategies and organizational performance in the hospitality industry in Nigeria. Doctoral Dissertation, Delta State University, Abraka, Nigeria. www-.grin.publishing.

Efendioglu, A.M., and Karabulut, A. T. (2010). Impact of strategic planning on financial performance of companies in Turkey. International Journal of Business and Management.

Elem, R. (2008). Economic opportunities available in the Nigerian maritime sector. The Voyage Magazine, April, p.12.

Eromafuru, E. G. (2016). The foundation of management: theory and practice. First ed. Precision Limited, Enugu.

Flamholtz, E., and Kurland, S. (2006). Making strategic planning work : a case study of country wide financial. Handbook of Business Strategy, Vol. 7 No.1, pp. 187- 193.

George, B., Walker, R. M., and Monster, J. (2019). Does strategic planning improve organizational performance? A meta-analysis.Public Administration Review, Doi : 10.1111/puar.13/04.

Gumel, B. (2019). The impact of strategic planning on growth of small business in Nigeria. SEISENSE Journal of Management, Vol.2 No.1, pp.69-81. https:/doi.org/10.33218/sj-om.v2i1.85.

Hani, J. B.(2021). The impact of human resource planning in achieving the strategic goals of the firm with moderating role of organizational innovation. International Journal of System Dynamic Applications, Vol. 10 No.4, pp.(..)

Heinz, W., Mark, V.C.,and Harold, K. (2011). Management : a global and entrepreneurial perspective. 13th edition. Tata McGraw Hill Education Private Limited , New Delhi.

James, V. E. (2009). Development of a strategic planning process model for division 1-A intercollegiate athletic department. Doctoral project, University of Pittsburgh.

Jayawarna, S., and Dissanayake, R. (2019). Strategic planning and organisational performance : a review on conceptual and practice perspective. Archives of Business Research, Vol. 7 No.6, pp. 171-180. Doi : 10.14738/abr.76.6684.

Joe, D. (2015). Real-time strategic planning for organisational effectiveness. Presentation, La Piana Consulting, pp. 1-17.

Jovica, P., Edmundas, J., and Laima, J. (2016). Significance of strategic planning for results of sport organisation. Ekonomika Management, Vol. 4 No 19,pp. 56-71.

Karel, S., Adam, P., & Radomir, P. (2018). Strategic planning and business performance of micro, small, and medium sized enterprises. Journal of Competitiveness,Vol. 5 No.4, pp. 57-72.

Kathleen, M. I., Ralp, A. G., Brent, D. R., & Shemi, T. (n.d). Evaluating the impact of strategic planning in higher education. Educational Planning, Vol. 23 No. 1, pp. 35-47.

Khan, M. W. J., & Khalique, M. (2014). A holistic review of empirical studies of strategic planning and future research

avenues. International Journal of Academic Research in Economics and Management Sciences, Vol. 3 No.6, pp.1-15.

Lado, A A., and Wilson, M. C. (1994). Human resource systems and sustained competitive advantage : a competency based perspective. Academy of Management Review, Vol.19 No.4, pp.699-727.

Madhani, P. M.(2010). Resource based view (RBV) of competitive advantage : an overview. The Icfai University Press.

Mohamed, S. (2010). The strategic importance of tacit knowledge management activities in construction. Construction Innovation, Vol.10 No.2, pp.138-162.

Mohammad, S. R., & John, M. (2012). The study on strategic planning and organizational performance in the regional government owned banks in Indonesia. International Journal of Humanities and Applied Sciences, Vol. 1 No.3, pp. 98-102.

Mohammed, S. A., Rushami, Y., and Hassan, A. (2020). The effect of innovation and strategic planning on enhancing organizational performance of Dubai Police. Innovation and Management Review, Vol. 17 No.1, pp. 2-24. Doi: 10.1108/INMR-06-2018-0039.

Moody, D. W. (n.d). Importance of strategic planning. Paper presented at the King George County, Department of Fire, Rescue and Emergency Services, Virginia.

Murriithi, S. M., Louw, L., and Radioff, S. E. (2018). The relationship between strategic thinking and leadership effectiveness in Kenyaindigenous bank. South African Journal of Economic Management Sciences, Vol.21 No.1, pp.17-41. https://doi-.org/104102/sajems.v21i.1741.

Nasratullah, O. (2016). Impact of strategic on organizational performance in private higher education and institutions in Nangahar, Afghanistan. International Journal of Research Publication, Vol. 93 No.1, pp. 372-389. Doi : 10.47119/IJRP10-0931120222749.

Odongo, M. S., and Dutche, O. (2015). Effects of strategic planning on organisational growth: a case study of Kenya Medical Research Institute, Vol.5 No 9, pp. 1-15.

Ogbor, J.O. (2019). Business policy and strategic management: corporate, business and functional strategies. 1st ed. Institute for entrepreneurship and strategic studies, Lagos.

Ogonji, M. (2014). Strategic planning in non-profit organizations : a content analysis of best practices. Dissertation. Trinity Washington University.

Okolocha, (2020). A key organizational performance of selected Nigerian banks. International Journal of Research Publication, Vol.52, pp. 23-37.

Omoke, V., Aturu, A. C., Nwaogbe, O. R., Ajiboye, A. O., and Diugwu, I. (2019). Analysis of the impact of port operations on the Nigerian economy: a focus on Apapa seaport. Available at: http://repository.futminna.edu.ng:gogo/jspiu/handle/123456789/7641.

Osadume, R. C., and Edih, U. O. (2020). Port revenue performance and economic growth: the Nigerian Port Authority perspective, 2010-2019. Logi-Scientific Journal on Transport and Logistics, Vol. 11 No.2 pp.1-11. Doi: 10.2478/logi-2020-0010.

Oyoo, E. A.(2014). Determinants of strategic planning in organizations working in turbulent environment : a case study of Kenya Red Cross Society. Dissertation, School of Business, University of Nairobi.

Paris, K. A. (2003). Strategic planning in the University (online). Available : https://www.cuhk.edu.hk/u.planning.office-/documents/other-strategic-planning/paris-2003_strat-plan-u.pdf.

Paauwe, J. (1996). HRM and performance : the linkage between resources and institutional context. RIBES Paper, 9854. RIBES, Erasmus University Rotteru, the Netherlands.

Peretomode, V. F.(2014). The role of the maritime industry and vocational and technical education and training in the economic development of Nigeria. IOSR Journal of Humanities and Social Sciences, Vol.19 pp. 45-50.

Philips, P.A.(2000). The strategic planning/finance interface : does sophistication really matter? Management Decision, Vol.38 No.8, pp. 541-649.

Rudd, J. M., Greenley, G. E., Beatson, A. T., and Lings, (2008). Strategic planning and performance : extending the debate. Journal of Business Research, Vol. 61, pp. 99-108.

Salami, C.G.E., Ajobo, R. T., and Okwuise, U. Y.(2013). Human resource management : harnessing the most important research on organizational effectiveness in the 21st century. Most Virtue Publishers.

Sandra, M., Pooe, D.,and Dhurup, M. (2014). Strategic planning and it's relationship with business performance among small and medium enterprises in South Africa. International Business and Economic Research Journal, Vol. 13 No.3, pp. 70-83.

Shu-Hsiang, C., Jaitip, N., & Donaldson, J. A.(2018). A strategic planning process model for developing educational resources. International Journal of Information and Education Technology, Vol. 8 No.5, pp. 362-368. Doi : 10.18178/ijiet.201-8.8.5.1064.

Sophia, O. M., and Owuor, D. (2015). Effects of strategic planning on organisational growth: a case study of of Kenya Medical Research Institute. International Journal of Scientific and Research Publication, Vol. 5 No.9, pp. 1-10.

Spee, A. P., and Jarzbkowski, P.(2011). Strategic planning as communicative process. Organizational Studies, Vol. 32 No. 9, pp. 1217-1245. Doi : 10.1177/0170840611411387.

SS&C Blueprism (2023). Unleashing unlimited possibilities: delivering transformational results., 1-13. Available at ; www.blueprism.com.

Steve, O .H. (2005). Decision theory : a brief introduction. Research project. Department of philosophy and the history of technology, Upsala University, Stockholm.

Steve, O . H. (1990). An overview of decision theory. SKN Report 41.

Vargo, J. and Serville, E. (2011). Crisis strategic planning for SMEs : findings the silver lining. International Journal of Production Research, Vol. 49 No. 18, pp. 5619-5635. Doi: 10.1080/00207543.2011.563902.

Vincent, A . O., Geraldine, E. U., and Elijah, S .E. (2010). Social sciences research : principles, methods and applications. First ed. El-DEMAK Publishers.

Walker, J. (1978). Linking human resource planning and strategic planning. Human Resource Planning, Vol.1 pp. 1-18.

Wijetunje, W.A.D.S., and Pushpa Kumari, M. D. (2014). The relationship between strategic planning and business performance : an empirical study of manufacturing SMEs in Western Province in Sri Lanka. Kelaniya Journal of Management, 3(1), 23-41.

Wright, P. M., Dunford, B.B., and Snell, S. A.(2001). Human resources and the resource based view of the firm. Journal of Management, Vol. 27, pp. 701-721.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 157–162

ISSN: 1697-4840, www.jmr.unican.es

Empirical Analysis of The Effect of Administrative Internal Cost on Value of Maritime Firms in Nigeria

Omorho Humphrey Onoriode[1,*], Edefetano Lucky Oboreh[2]

ARTICLE INFO

Article history:
Received 3 Aug 2023;
in revised from 24 Aug 2023;
accepted 16 Sept 2023.

Keywords:
Administrative Cost, Corporate Board Cost, Employee Bonus, Firm Value.

ABSTRACT

This study evaluates the relationship between Administrative Internal Cost and value of Maritime firms in Nigeria between 2018 and 2022 (five years). The study adopted ex-post facto research design and used panel data collected from the financial report of the firms under the Maritime sector within the period covered by the study. The Administrative Internal Cost was proxy by: Corporate Governance Board Cost, Audit fee, Corporate reporting cost, and Employee bonus/incentive as explanatory variables (administrative internal cost) while firm value was used as response variable. The data collected were analyzed using regression analysis, however the study conducted some preliminary analysis such as descriptive statistics, correlation analysis, and variance inflator analysis to ascertain the normality and check for the presence of multi-co linearity among the variables used. The study finds that administrative internal costs have positive influence of about 41.2% on the level of firm value among maritime firms in Nigeria. The specific finding shows that corporate governance board cost has positive and significant relationship with firm value. Audit fee has positive and significant relationship with firm value. Employee bonus incentive has positive and significant relationship with firm value. Corporate reporting cost has negative and insignificant relationship with value of maritime firms in Nigeria. The study recommends among others that adequate allocation should be given to the corporate board to enable them discharge their oversight function which enhances the value of maritime firms in Nigerian..

1. Introduction.

Modern corporations are characterized by a separation of ownership and control, with the owners appointing professional managers to oversee their companies. This separation of ownership and management is the foundation of the agency theory. Ownership becomes increasingly passive, while management is given a sufficient degree of autonomy to pursue objectives that may or may not be in line with the interests of the owners or principal of the company (Xiao, 2009). The owners (the principal) employ the services of a professional manager (the agent). As a result of the separation, the role of the owners has become more passive, while the manager is relatively free to pursue objectives that are not necessarily in line with the objectives of the owners. Both the principal and the agent consider wealth maximization to be objective (rational people). The agent has the authority to make essential decisions regarding the operations of the firm, but may select alternatives that directly benefit them at the expense of the shareholders. Managers may, for example, be tempted to take advantage of resources that are not in the company's best interest and utilize them for personal gain. According to Xiao (2009), the separation between management and ownership in contemporary corporations provides the manager with the incentive and opportunity to engage in activities

[1]PhD in Business Administration, Department of Business Administration, Faculty of Administration and Management Sciences, Delta State University of Science and Technology, Ozoro, Delta State, Nigeria. E-mail:onoriodehumphrey74@gmail.com.

[2]PhD in Business Administration, Department of Business Administration, Faculty of Administration and Management Sciences, Delta State University of Science and Technology, Ozoro, Delta State, Nigeria. E-mail: oborehlucky2014@gmail.com.

[*]Corresponding author: Omorho Humphrey Onoriode. E-mail Address: onoriodehumphrey74@gmail.com.

that are in the company's interest rather than those that are in the owners' interest. This has led to the emergence of an agency issue. Ammari (2016), Ammari (Amdouni (Zemzem (Ellouze)) and Ammari (Ellouze) (2016) state that the primary source of the agency issue is the disparity between the objectives of the owners and those of the owners. In a corporate structure in which the owners are not integrated into the management structure, the likelihood of conflict is increased. In order to ensure that the objectives of the manager are in line with the objectives of the owners, owners may adopt certain incentive or monitoring measures. These measures necessitate the expenditure of a significant amount of money, commonly referred to as agency costs. These cost implications can have an impact on the owners' wealth. However, as previously discussed, these costs can arise if the advantages to be gained outweigh the costs incurred. According to the authors of the opinion paper "Administrative Cost as All Costs Billed by Shareholders to Encourage Managers to Maximise Shareholder Wealth Rather Than Act in Their Self Interest", monitoring managers and incentives should be implemented to align both interests. On the basis of the foregoing, the administrative costs include; monitoring (e.g. audit, governance, information asymmetry reduction, etc.), bonding costs (e.g., bonus, stock option, etc.), and residual loss-losses that arise from legal costs associated with conflicts of interest between principals and agents. How these costs affect the firms' value is the subject of this study. The specific objectives of this study are as follows:

1. Examine the relationship between corporate governance costs and firm value,
2. Determine the extent of the relationship between auditor's fees and firm value.
3. Assess the relationship between corporate reporting costs and firm value.
4. Evaluate the relationship between employee bonuses and firm value.

In order to accomplish these goals, the following hypotheses were formulated in a form of null; corporate governance cost, auditor's fee, corporate reporting cost, employee bonuses / incentives do not have a significant positive impact on the firm's value.

2. Literature Review.

2.1. Firm Value.

Firm value is a measure of a firm's value in the eyes of its stockholders or investors. It is a measure of the price at which the firm's stock would be traded in a competitive market. Firm values are typically measured through the Tobin Q model. A firm's value is typically measured through Tobin's Q. The Tobin Q model is a model that relates investment to a firm's stock firm valuation. It is intended to reflect the present discount rate of expected future profits. Chen (2019) cited Scott (2000) as an example of a statistic that would be sufficient for investment rates for perfectly competitive firms with consistent returns to scale technology. Scott (2000) shows that average Q is the ratio of the firm's maximized value to its replacement cost of its current capital stock. The standard empirical measure, commonly referred to as Tobin's Q, further supposes that the optimal value of a firm can be determined by the stock firm valuation. On the assumption that the stock firm valuation captures all relevant information regarding expected future profitability, substantial coefficients on cash-flow variables after adjustment for Tobin's Q cannot be attributed to further information about current expectations. However, if the conditions of the Tobin's Q are not met, or if the stock firm's valuations are affected by 'bubbles' or any other factor other than the current discounted value of the expected future profits, then Tobin's Q would not provide all pertinent information regarding the expected future return on current investment.

2.2. Administrative Cost.

Bhat (2018) defines administrative costs as the internal costs associated with the reduction of information asymmetry and the reduction of conflicts of interest among principals and agents within a firm.

2.3. Corporate Governance Board Cost.

Corporate governance is the system of rules, procedures and processes by which a company is managed and regulated (Chen, 2019). The board of directors is responsible for influencing corporate governance, as it represents the balance of interests of the various stakeholders of the company. The board is primarily responsible for making essential decisions, which have a direct impact on the firm's short and long-term viability, among other factors. The corporate board is responsible for acting on behalf of shareholders, and monitors and limits the activities of managers. (Krishnan, 2008; Chen, 2019). This is to guarantee that managers' actions are in the best interests of shareholders, thus maximizing shareholder value. Monitoring cost is the cost of running and maintaining a board of directors. It is the cost of maintaining the board and ensuring that they fulfill their duties. The company allocates a considerable amount of resources to the Board of Directors, such as: sitting allowances, travelling allowances, postage, telecommunications, etc. As members of the Board are drawn from various occupations and geographical locations, the meetings of various sub-committees of the Board necessitate funding. The corporate board cost is the total expenditure required to enable the board to perform its duties and discharge its responsibilities in an appropriate manner.

2.4. Auditor's Fee.

An audit fee is an amount of money that a public accountant charges a client for the services rendered to the client in the context of an audit or financial statement review. It is the amount of money a professional accounting firm charges a client for an annual audit and review of financial statements (Scott, 2000). The cost of an audit fee is determined by the complexity of the services rendered, the amount of work to be completed, the risk associated with the services, the level of expertise required, and other relevant professional factors. In the context of this study,

the audit fee represents the amount of money an auditor charges a client to complete an audit assignment. The audit fees charged for auditing assignments may reflect the amount of time needed to carry out the audit work, which according to the opinion of the group of auditors Mohammad Asghar, Asgar, Safdar and Hamid (2015), is related to the size of the audited company, as per the opinion of the same group of auditors (Hossein Zohreh, Roghaieh, 2013). The auditor is employed to review the report prepared by management and to provide its professional opinion on whether the report provides a true and equitable view. The auditor examines the annual report to determine if it meets all applicable standards.

2.5. Employee Bonuses/Incentives.

An employee bonus is an additional benefit an employee receives from the firm in exchange for the services rendered during the period considered, as defined by Kiamehr (Moghaddam & Alipour, 2015) and others. Employee bonuses may be paid in cash, in kind or in the form of a stock option. Employee bonuses are provided to employees as a means of motivating them and as a reward for loyalty and achievement of objectives. Sang, Mooweon & Jongchul (2018) stated that bonus payments act as a performance-enhancing tool. Consequently, the correlation between bonus payments and firm performance is likely to differ from sector to sector. According to Bhat, Chen, Jebran, and Bhutto (2018), top executives receive bonuses as compensation for putting forth a quality effort on the job. The authors also pointed out that benefits like meals, entertainment, and travel expenses assist businesses in forging beneficial relationships with key decision-makers and business partners. Employee bonuses are simply the monetary compensations and other non-monetary rewards that employees of a company receive in recognition of their service to the organizations. Typically, it consists of a combination of bonuses, shares of, or call options on, the company's stock that has been tailored to take into account governmental regulations, tax law, the preferences of the company and the employee, as well as rewards for performance.

3. Theoretical Framework.

Agency theory is the foundation for this study. The agency theory, developed by Jensen and Meckling in 1976, is one of the theoretical tenets guiding the relationship between the shareholder (principal) and the director (agent). According to this theory, a company's managers act as both the principal and the principal's agent. Although investors have extra money to invest, they hire managers to help them because of limitations like a lack of time and managerial expertise. Managers who receive compensation for their efforts run this fund, which invests in successful businesses in order to generate good returns. But agency issues developed as a result of the separation of ownership and management, as well as the conflicting interests of the owners and the managers they hired. The principal-agent problem refers to the difficulty of persuading one party to act on behalf of another. The principal-agent problem occurs when a principal pays an agent to carry out specific tasks that are advantageous to the principal but costly to the agent, and when there are aspects of the performance that are expensive to watch. According to Jensen and Meckling (1976), this is the degree to which the owners who make up the residual claimants (the owners) receive returns that are less than what they would be if the owners had direct control over the company. As long as they will profit financially, managers are free to start stripping assets and then go on to buy lower-value assets. In order to align the manager's and owners' goals of maximizing wealth, agency problems can be handled or reduced by using administrative costs.

4. Methods.

The longitudinal research design and pooled data were both used for the study. The study makes no attempt to change the nature or value of the data used to evaluate the effect of administrative internal costs on maritime firms in Nigeria. The data used, which has time series and cross sectional characteristics, was the primary factor in the ex-post facto design decision. In this study, ten maritime businesses that operate in different parts of Nigeria were used. These companies are situated in the states of Lagos and Rivers, respectively. All maritime businesses operating in Nigeria as of December 2022 make up the study populations. Firms with the necessary data during the study period make up the sample size. The companies used are: United Africa Lines (Rivers State), African European Lines (Nig) Limited (Lagos State), Air Sea Freighter Limited (Rivers), Alan Caray Technical Ltd (Lagos State), Bhn Transport & Logistics Limited (Rivers), Blue Star Shipping Line Limited (Lagos), East Atlantic Cargo & Marine Services Limited (Rivers), Equatorial Marine Oil & Gas Company Limited (Lagos), Gasop Nig. Limited (Rivers) and Gulf Agency& Shipping (Nig.) Limited (Lagos). The study also used cross-sectional data. Suitable descriptive and inferential statistics were used to analyze the data collected.

4.1. Model Specification.

The model of this study was adopted from the work of Chen, (2019). The Chen model is MB = (CGC,ADF), where MB is market to book value of the firm, while CGC = corporate governance cost, and ADF = auditor fee. The model was modified to suit the variables to be used. Hence the model for the study was based on the variables of the study.

$$TOBIN = f(CBCOS, AUDFE, REPCOS, EMBON) \quad (1)$$

This can be econometrically expressed as:

$$TOBIN_{it} = \beta_0 + \beta_1 CBCOS_{it} + \beta_2 AUDFE_{it} + \beta_3 REPCOS_{it} + \beta_4 EMBON_{it} + \mu_{it} \quad (2)$$

Equation 1 is the linear regression model used in testing the null hypotheses.

Where:

TOBIN = Tobin q;

CBCOS = Corporate governance board cost;
AUDFE = Auditor's fee;
REPCOS = Corporate reporting cost;
EMBON = Employee/incentives bonus;
β_0,= Constant;
β_1, to β_4, = are the coefficient of the regression equation.
μ = Error term;
i= is the cross section of firms used;
t = is year (time series).

Table 1: Normality test.

Variable	Obs+	W	V	z	Prob>z
TOBIN	110	0.2044	14.048	6.2254	0.02010
CBCOS	110	0.7576	311.36	44.886	0.00000
AUDFE	110	0.3457	425.93	52.038	0.00000
REPCOS	110	0.3452	557.85	56.004	0.00000
EMBON	110	0.2565	63.046	16.223	0.00000

Source: STATA 13.

The Shapiro normality test shows that auditors fees, reporting cost, employee incentives, and corporate board cost, are normally distributed at one percent significance; while firm value is normally distributed at 5 percent significant level. The normality test result reveals that all the variables used are normally distributed. This indicates that the result of the analysis can be relied upon in making generalization and policy formulation. The result of the Shapiro normality test is similar to the normality test result produce by the Jarque-Bera statistics probability.

Table 2: Correlation Analysis.

	TOBINQ	CBCOS	AUDFE	REPCOS	EMBON
TOBINQ	1.000000				
CBCOS	0.121906	1.000000			
AUDFE	0.203808	0.005490	1.000000		
REPCOS	0.021132	0.242134	0.047053	1.000000	
EMBON	0.163810	0.162505	0.211155	0.215082	1.000000

Source: Researchers Summary of e-view 9 (2023).

The findings from the correlation analysis table shows that firm value (tobin q) have positive association with Board cost (0.12), corporate reporting cost (0.02), employee bonuses (0.16) and audit fee (0.20). The positive association reveals that audit fee, corporate Board cost, corporate reporting cost and employee bonus incentives positively associate with firm value. In checking for multi-co linearity among the variables used, the study noticed from the correlation analysis result that no two explanatory variables were perfectly correlated. This indicates the absence of multi-co linearity problem in the model used for the analysis and also justifies the use of the ordinary least square. This was confirmed by the result of the variance inflation factor (VIF) below.

Table 3: Variance Inflation Factor Test.

Variable	VIF	1/VIF
TOBIN	1.01	0.99009
CBCOS	1.10	0.91009
AUDFE	1.00	0.90990
REPCOS	1.01	0.88007
EMBON	1.30	0.76923
Mean VIF	1.082	----

Source: Authors.

The Variance inflation factor test result table above shows the mean value of 1.082. The mean value is less than 10 rejection benchmark. The mean value indicates the absence of multi- co linearity in our model. This result (Variance inflation factor test result) confirms the finding from the correlation analysis which shows the absence of multi-co linearity using 75 percent acceptance region in determining the level of association among the variables used.

Table 4: Hypotheses Testing.

Dependent Variable: TOBIN
Method: Panel Least Squares
Date: 12/08/20 Time: 9:18
Sample: 2011 2020
Periods included: 10
Cross-sections included: 11
Total panel (balanced) observations: 110

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	13.71579	2.546013	5.387164	0.0000
REPCOS	-1.361401	2.188265	-0.622137	0.5347
AUDFE	4.565215	0.929530	4.911317	0.0000
EMBON	0.095388	0.041948	2.273958	0.0163
CBCOS	2.573406	0.799674	3.218069	0.0015

R-squared	0.439350	Mean dependent var	0.890335
Adjusted R-squared	0.412112	S.D. dependent var	3.489996
S.E. of regression	24.30988	Akaike info criterion	4.843317
Sum squared resid	1603.389	Schwarz criterion	5.288589
Log likelihood	337.2551	Hannan-Quinn criter.	5.023512
F-statistic	13.22928	Durbin-Watson stat	2.13300
Prob(F-statistic)	0.004693		

Source: Researchers summary of OLS regression Analysis from E-view 8 (2023).

In the regression table above, the study observed from the firm value (tobin q) model result an R-sq of 0.439 and R-sq (adj) of 0.412, respectively. The R-sq adjusted value indicates that the selected Agency internal cost variables jointly have about 41.2 percent impact on the reporting lag of firm used in the study. The F-statistics value of 13.23 and its probability value of 0.000 shows that the regression model is well specified and the specification is statistically significant at 1% levels. The Durbin Watson which reveals the presence of autocorrelation, it value of 2.133 (approximated into 2) reveals the absence of autocorrelation in our model. Hence the variables used in model can be relied upon as administrative internal cost variables in driving firm value (tobin q).

Hypothesis 1: Corporate Governance board cost has no significant effect on Firm value

The analysis result showed a coefficient value of 2.57 and a P-value of 0.0015. The coefficient value shows that Corporate Governance board cost has a positive effect on firm value (tobin q). This reveals that increase in Corporate Governance board cost can increase the value of the firm. The probability value reveals that Corporate Governance board cost has significant effect on the firm value (tobin q) of maritime firms in Nigeria. Based on the result, the study rejects the null hypothesis and accepts the alternate hypothesis, which says that, corporate governance board cost has significant effect on firm value (tobin q).

Hypothesis 2: Audit fees has no significant effect on firm value (tobin q).

The analysis result showed a coefficient value of 4.57 and a P-value of 0.000. The coefficient value reveals of 4.57 shows that that audit fees has positive influences on the level of firm value (tobin q). This indicates that the higher the fee paid to auditor, the thorough they tend to carry out their responsibility the better the user relied on the report the higher the value of the firm. The probability value shows that the relationship between audit fee and firm value (tobin q) of maritime companies in Nigeria is statistically significant. This means increase in Audit fee positively and significantly leads to increase the firm value. Based on the analysis result, the study rejects the null hypothesis and accepts the alternate hypothesis. The study concludes that Audit fee has significant relationship with firm value (tobin q) of maritime firms in Nigeria.

Hypotheses 3: Corporate reporting cost has no significant effect on Firm value.

The analysis result showed a coefficient value of -1.361 and a P-value of 0.534. The coefficient value which reveals the degree of influence corporate reporting cost has on firm value (Tobin q) shows a negative value. This means that corporate reporting cost negatively influences the level of firm value (Tobin q) among maritime firms in Nigeria. The high cost of publishing the corporate annual reporting if invested in project with positive net present value can enhance the profitability and the value of the firm. This shows that higher corporate reporting cost can lead to lower firm value. The probability value of 0.534 shows that the effect of corporate reporting cost has on firm value (Tobin q) among maritime companies in Nigeria is insignificant. Based on the analysis result, the study rejects the alternate hypothesis and accepts the null hypothesis. The study therefore concludes that corporate reporting cost has negative insignificant effect on the firm value of maritime firms in Nigeria.

Hypotheses 4: Employee bonus incentive has no significant effect on Firm value.

The analysis result showed a coefficient value of 0.095 and a probability value of 0.016. The coefficient value which reveals the degree of influence employee bonus incentives has on firm value (Tobin q) is positive value. This means that employee bonus incentive positively influences the level of firm value. This shows that higher employee bonus incentives can lead to higher firm value among maritime firms in Nigeria. The probability value of 0.016, shows that the relationship between employee bonus/incentive and value of maritime companies in Nigeria is significant. Based on the analysis result, the study rejects the null hypothesis and accept the alternate hypothesis, it therefore concludes that employee bonus incentive has significant effect on firm value among maritime firms in Nigeria.

5. Discussion of Findings.

The finding reveals that corporate governance board cost has a positive and significant cause effect relationship with the firm value of companies in Nigeria. The operations and activities of the board require funding. For the board to effectively carry out its responsibility, it requires adequate funding and diligent use of available resources. The more funding makes available for the board to carry out its function, the more likely they will contribute the growth of the firm and the value of the firm. This finding is in line with the finding from similar studies like that of Chen (2019), Bhat, Yan, Khalil and Bhutto (2018) and Ammari, Sarra, Zemzem and Ellouze (2016) on Corporate governance, cost and firm value.

Auditors' fee has a strong positive significant effect relationship with value of maritime companies in Nigerian. A highly paid auditor will seems to be more thorough compare to auditor who accepted the offer as a means to meet need. This finding suggests that allocating high amount for audit assignment can attract high quality auditor irrespective of the size of the firm, and using such high quality auditor give more confidence to the user and investors. This can lead to an improvement in the firm value. This result is in line with the finding from similar study of Martinez and Moraes (2014), Vasconcelos (2017) study finding. The study also finds that corporate reporting cost has a negative causal effect relationship with firm value among maritime companies in Nigeria. This shows that increasing the cost of producing annual report can have negative impact on the value of maritime firms in Nigerian. The finding also shows that employee bonus/incentives have a positive significant effect on value of firms in Nigeria. This finding demonstrates that the form of audit firm used will positively affect the degree of firm value for auditors. The findings are in line with the findings of similar study of Scott (2000).

Conclusions.

The company law separate ownership from control / management. This separation has lead to the desire to achieve divergent interest by the owners and the manager they hired. To align these interests, policy makers establishes reporting and monitoring mechanism as a way of reducing information asymmetry and ensure adequate disclosure of operating activities to the owners. However, this has not fully solved the problem. To reduce the problem, the owners incurred additional cost like, cost of corporate governance cost, cost of engaging auditor, granting of bonus incentive and cost of publishing their annual report. The findings of this study have indicated that the administrative internal cost is a key driver of firm value among maritime companies in Nigerian. The study therefore recommends that adequate allocation should be given to the corporate board to enable them discharge their function which enhances the value of maritime companies in Nigerian. Also, to enhance their value, maritime companies should consider paying auditor above other industry (however, consideration should be given to their financial performance). Managers should consider reducing the cost of publication of annual report by adopting e-reporting, as the cost of printing is negatively impacting on their firm. Furthermore, maritime companies in Nigerian should consider increasing their employee bonus/ incentive as it will lead to better firm value.

References.

Ammari A., Amdouni S., Zemzem A & Ellouze A (2016). The effect of monitoring committees on the relationship between board structure and firm performance**.** *Journal of Risk and Financial Management 4(1), 44-60.*

Bhat, K, Chen, Y, Jebran, C & Bhutto, N (2018) Corporate governance and firm value: a comparative analysis of state and non-state owned companies in the context of Pakistan. *The International Journal of Business in Society* 3 (1), 31-48.

Chen (2019). Corporate board and their responsibilities in china. *International journal of economics 3(2) 71-83.*

Chrisostomos F. & Ozkan, A. (2004). Agency costs and corporate governance mechanisms: Evidence for UK firms. Department of Economics and Related Studies, University of York, Heslington, York, YO10 5DD, UK.

Hoang, L., Tran M., Pham V., Tran P. & Phuong, T (2019). Impact of agency costs on firm performance: evidence from Vietnam. *Organizations and Markets in Emerging Economies* 10 (2) 294–309.

Hossein J, Zohreh H, & Roghaieh L. (2013). Investigation of the effect of agency costs on firm performance of listed firms in Tehran Stock Exchange. *European online journal of natural and social sciences* 2(3), 771-776.

Kalim B, Yan C, Khalil J & Niaz A (2018). Corporate governance and firm value: a comparative analysis of state and non-state owned companies in the context of Pakistan. *The International Journal of Business in Society* 3, (5), 30-44.

Kiamehr1., M., Moghaddam A., Alipour, S &, Hajeb, H. (2015). Examining the impact of institutional ownership on monitoring cost: the case of Iranian firms listed on Tehran stock Exchange. *International Journal of Academic Research in Accounting, Finance and Management Sciences* 5(4) 22-39.

Krishnan, G., & Visvanathan, G. (2008). Does the sox definition of an accounting expert matter? The association between corporate board directors' accounting expertise and accounting conservatism, 827-857.

Martinez A. & Moraes, A (2014). Association between independent auditor fees and firm value: a study of Brazilian public companies. *Journal of Modern Accounting and Auditing, 10(4), 442-450.*

Mohammad K., Asghar A., Safdar A., & Hamid R (2015). Examining the impact of institutional ownership on monitoring cost: the case of Iranian firms listed on Tehran stock Exchange. *International Journal of Academic Research in Accounting, Finance and Management Sciences* 5(4) 22-39.

Sang C., Mooweon R., & Jongchul Y. (2018). Foreign monitoring and audit quality: evidence from Korea. *European online journal of natural and social sciences* 2(3), 771-776.

Scott J. (2000). Executive compensation and firm performance: Big carrot, small stick. *Stanford Institute for Economic Policy Research. Stanford, CA*. 94305.

Vasconcelos, M. (2017). Agency costs, firm value, and corporate investment agency. *A thesis to obtain the degree of Doctor from the Erasmus University Rotterdam.*

Xiao, S (2009). How do agency costs affect firm value? evidence from China. *European Online Journal Of Natural And Social Sciences* 2(3), 771-776.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 163–171

ISSN: 1697-4840, www.jmr.unican.es

Relation between the ship's biofouling and the places they come from: Case study of a merchant ship in the Bay of Biscay

S. Álvarez Pulgarín[1], D. Menéndez-Teleña[2,*], V. Soto-López[3]

ARTICLE INFO

Article history:
Received 4 Aug 2023;
in revised from 24 Aug 2023;
accepted 21 Sep 2023.

Keywords:
Maritime Transport, Hull, Biofouling, Invasive Species, Ship Resistance.

ABSTRACT

Biofouling is the accumulation of aquatic organisms on surfaces immersed into the water such it could be the hull of a ship. What is more, biofouling generates several inconveniences in the development of a ship's operation. The first one arises when they act as a vehicle for the transfer of possible invasive exotic species, which can also travel through ballast water from one region to another and creates what is known as biological contamination. The second is the decrease in speed caused by the friction which affects the performance during transit. Under this problematic situation, a case of study has been done in a merchant ship in the Bay of Biscay to predict which invasive species could have been attached to the hull according to the vessel's voyages and to assess the most affected parts of the hull by biofouling.

1. Introduction.

For millions of years, marine organisms have been separated by geographic barriers, unable to disperse over long distances. However, as transportation has become faster and more accessible, these barriers have been disappearing (Castellanos-Galindo et al., 2020). During 2020 the world merchant fleet increased by 3%, reaching 99,800 vessels and, during the period 2022-2026, maritime trade is expected to have an annual growth of 2.4% (UNCTAD, 2021). This intense maritime traffic has provided opportunities for thousands of species to be transported to new habitats (Williams et al., 2013), via ballast water or attached to the hull of ships in the form of fouling (Sharma, 2006).

On the one hand, ballast water provides stability to the vessel and is essential to maintain safe conditions during the voyage when it is not loaded. The ballast is stored in dedicated tanks or in empty cargo holds at the time of discharge of cargo. Then when the cargo or bunkers are loaded the water is deballasted (International Maritime Organization, 2004). The amount of ballast water carried can be as high as 113,000 tonnes for certain types of ships such as bulkcarriers, 45,000 tonnes for tankers or 6,000 tonnes for general cargo ships. Therefore, ballast water consists of port water, which may contain many viable exotic organisms even after long voyages (Globallast Partnerships, 2017).

On the other hand, the biofouling, marine organisms that attach themselves to the hulls of ships, is considered to be the main reason for unintentional entry and distribution of species according to European regulations (Ashton et al., 2016). The IMO defines biological pollution as *"accumulation of aquatic organisms, such as microorganisms, plants and animals on surfaces or structures submerged in or exposed to the aquatic environment"* (International Maritime Organization, 2022).

Among the European seas, the Mediterranean is the most affected by the introduction of species, mainly due to its worldwide connection through the Suez Canal and the intense maritime traffic (Tsiamis et al., 2020). The Convention on Biological Diversity (CBD) adopted at the Earth Summit in Rio de Janeiro in 1992 considers both ballast water and fouling on the hull of ships as subcategories within the vector of species

[1]Higher School of Civil Navy belonging to the University of Oviedo; Blasco de Garay, s/n 33394 Gijón, Asturias, Spain; E-mail Address: UO265597@uniovi.es.

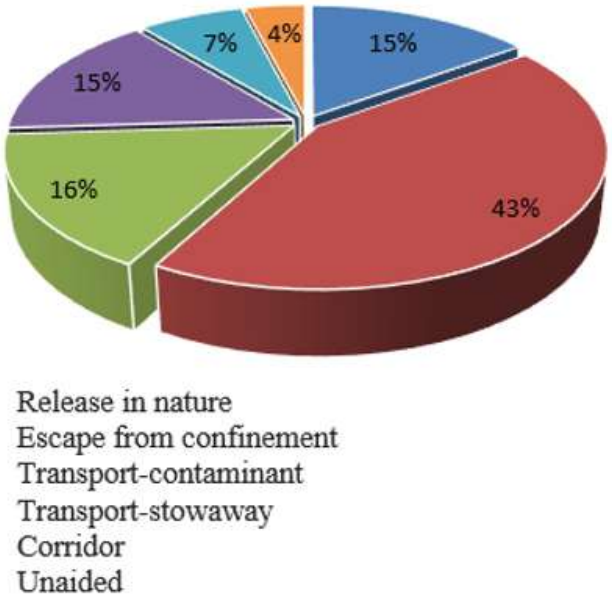
[2]Department of Marine Science and Technology of University of Oviedo; E-mail Address: menendezdeva@uniovi.es.

[3]Department of Marine Science and Technology of University of Oviedo; E-mail Address: sotoveronica@uniovi.es.

[*]Corresponding author: D. Menéndez-Teleña E-mail Address: menendezdeva@uniovi.es.

introduction by transport-pollution (CBD, 2023). In Europe, this vector represents the 15% of the introduction pathways by which the species are transferred (Figure 1).

Figure 1: Pathways of introduction that have been used by IAS of concern to the EU.



Source: Adapted figure from (Ministry for the ecological transition and the demographic challenge [MITECO], 2022).

If these organisms are introduced outside their natural geographical range, the species is commonly referred to as alien, exotic, non-native or non-indigenous species (Ojaveer et al., 2017). These are any species outside the natural range either due to international or accidental human-mediated transport, or transport by natural processes (Ministerio para la transición Ecológica y el Reto Demográfico Gobierno de España, 2013). When they are in a new port they may begin to displace native species and disrupt local ecosystem (Cebrian et al., 2013).

Invasive Aquatic Species (IAS) are defined as any species that is introduced or establishes itself in an habitat and is an agent of change and threat to native biological diversity, either by its invasive behavior, or by the risk of genetic contamination (Boletín Oficial del Estado del Gobierno de España, 2007). The introduction of IAS, into new environments by ships has been identified by the International Maritime Organization, henceforth, IMO, as a major threat to the world's oceans and to biodiversity conservation. Multiple marine species that have been transported in ballast water or on the hulls of ships can survive and establish a reproductive population in the host environment, becoming invasive, displacing native species and multiplying to become pests (International Maritime Organization, 2019).

It must be considered that invasive species can have a great impact on the environment, the economy and even threaten human health because of their harmful or poisonous potential (Galil et al., 2015). Most of them have the ability to choose their location influenced by environmental inputs: factors such as light, gravity, hydrostatic pressure, temperature and salinity mainly affect their distribution (Pérez, 2012). When invasive aquatic species are introduced into a habitat that is not their own and manage to adapt, reproduce and colonize the environment, they pose a threat to the marine ecosystem (Kenworthy et al., 2018). They can physically and chemically modify the ground, compete for food and space, and act as predators preventing the development of native species (Iberdrola, 2022).

Fouling and ballast water are the main systems for the movement of invasive species from one region to another, as they have been the vector for the introduction of seven of the 49 IAS of concern in Europe (MITECO, 2022). Once the species becomes established in the new environment it is very difficult to eradicate (Coughlan et al., 2018). In cases where eradication is not possible, pest control is maintained, which can entail very high costs. For example, the economic costs of the zebra mussel plague in the Ebro River have been estimated at 11.6 million euros during the period 2005-2009 and today it has still not been possible to exterminate it from the area (Perez and Chica Moreu, 2006). Agricultural and fishing activity is also economically affected due to the alteration of the marine habitat of local fish and species (Durán, 2011). The IAS can even endanger public health, for humans, one of their most dangerous effects is that they carry diseases.

To control and prevent biological contamination, international organizations are adopting a variety of measures. In the case of fouling, antifouling paints are used to prevent the adhesion of species to the hull (Dafforn et al., 2011). These are coatings, paints, surface treatments, or devices used on board. Even if ships have recently had their hulls cleaned or a new antifouling coating system applied, they will still have some level of biological contamination. For years metallic compounds such as tributyltin or TBT have been used in antifouling systems, which were very effective in preventing hull fouling, but were also harmful to the environment as they were shown to persist in water (Amara et al., 2018). As indicated in the existing regulations of the International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS), the time it takes to apply this paint to the hull usually corresponds to the time between dry-dockings (International Maritime Organization, 2001). However, the focus should be put on the prevention of the introduction of invasive species through fouling on ships.

Regarding biofouling, the IMO has published recommendations for implementing certain operational practices on board to prevent the development of biofouling on the hull (International Maritime Organization, 2011). In contrast to the case of Ballast Water Management Convention (BWM) that regulates the introduction of invasive species, which will be fully implemented in September 2024 (International Maritime Organization, 2019).

Studies have shown that the biofouling process begins within the first few hours of a ship's immersion in water (International Maritime Organization, 2011). The biofouling that may be found on a ship is influenced by a range of factor, such as follows:

- Design and construction, particularly the number, loca-

tion, and design of niche areas (Ulman et al., 2019),

- Specific operating profile, including factors such as operating speeds, ratio of time underway compared with time alongside, moored or at anchor, and where the ship is located when not in use (e.g., open anchorage or estuarine port) (Davidson et al., 2009), and
- Maintenance history, including: the type, age and condition of any anti-fouling coating system, installation and operation of anti-fouling systems and dry-docking/slipping and hull cleaning practices (Davidson et al., 2016).

Fouling also plays an important role in the ship's drag, as it can have such an effect on the hull roughness that it doubles the frictional resistance compared to a clean hull (Montes Coto, 2009). The species remain attached in the areas where they are least affected by the friction of the water against the hull and remain there throughout the voyage until the vessel reaches the port of destination. This applies a greater resistance to the ship's movement and generates a lower performance during navigation (Schultz, 2007).

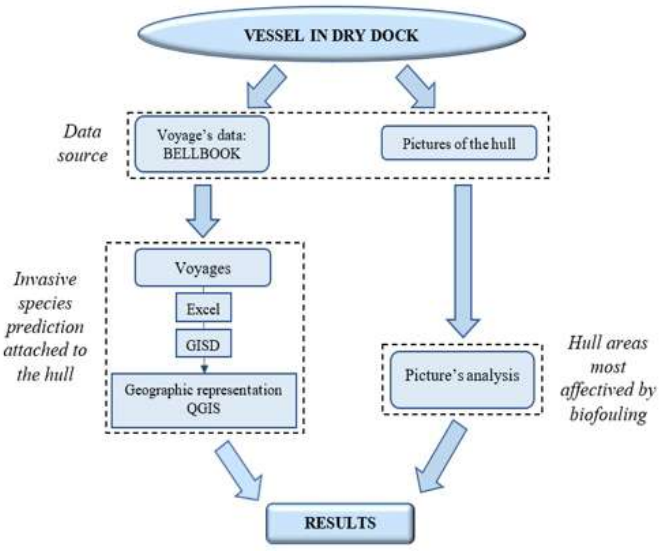
One of the reasons why organisms can be detached is the friction exerted by the water against the hull during navigation. This force does not affect the entire hull equally, allowing certain areas to be more susceptible to the accumulation of fouling. However, the variation in water characteristics between the port of origin and the port of destination, such as salinity or temperature, can help these species to be detached from the hull without causing any damage (Iacarella et al., 2020). This arises when they are not able to survive the conditions of the new habitat by accidentally detaching themselves from the hull of the ship.

This study aims to determine how merchant ships can generate biological pollution from fouling. To this end, a case study of a merchant ship entering dry dock has been carried out, predicting which invasive species have been able to adhere to the hull based on information from the ports it has called at since its last entry into dry dock. In addition, photographic data are taken of the affected hull areas to identify which parts of the hull are most affected by fouling and to be able to relate them to water friction during navigation.

2. Methodology.

In the Figure 2 you can see schematically the methodology of this research; that the following is explained in detail. The phases of this process are explained from the moment the ship enters the shipyard and the data are taken. The study of the prediction of species and the areas of the hull most affected by fouling is carried out to obtain the results of this study. First, to determine the possible introduction of species through biofouling, the data of the voyages are taken from the bellbook or logbook on board the vessel. This is the document that records the vessel's docking and undocking operations in port. Secondly, to determine which areas of the hull are most affected by the fouling, photographs are taken to analyze its condition in relation to the species it presents.

Figure 2: Overview of the methodology used.



Source: Authors.

2.1. Data source.

The information analyzed in this study is collected from a merchant vessel of 99.9 meters in length and 15.6 meters in beam that enters the Avilés Port Shipyard (Aviles Port, 2023) for maintenance work. The port of Avilés is located on an estuary in the Bay of Biscay, in the center of the Spanish Cantabrian coast. It has a storage area of 375,000 m2 and a berthing line of docks of 2 km, suitable to operate any type of merchandise (Figure 3). A total of 15 vessels of different dimensions enters this shipyard every year to carry out any maintenance task.

Figure 3: Location of the port of Aviles.

Source: Image adapted from Google Maps.

2.2. Invasive species prediction attached to the hull.

To predict the invasive species embedded in the hull, first, the ship's voyages were analyzed based on the information in the bellbook, where arrivals and departures to ports and anchor operations are recorded chronologically. In this way, the ship's itinerary since its last stop in dry dock was obtained. These data made it possible to identify the ports and anchorages visited by the vessel and information that made it possible to analyse possible invasive species attached to the hull.

To obtain the voyage data, this bellbook tracked and provided the port of call, the date and time of docking and undocking, the coordinates at the anchor position, the date and time the anchor was lowered and raised, and the navigation status. The data were acquired and organized simultaneously using the Microsoft Office Excel application. A table was made in which the collected data were laid out in an organized manner. As many rows were entered as the number of voyages made by the vessel compiling all travel information. The ship's voyages have to be analyzed to check the biological contamination that the ship may have caused taking into account the following situations:

- First, the navigational status that it has had throughout the voyages were considered. It could be found in a navigational state, docked in port or anchored (outside the port). It is important to point out these conditions since during the time the vessel is under navigation, the species have more difficulties to adhere due to the increased friction of the water with the hull. However, while docked or at anchor, the species have been able to attach more easily to the submerged structures of the vessel.
- Secondly, all the ports and anchorages visited by the vessel were presented chronologically, since these are the places where there is the possibility of species adhesion to the hull.
- Thirdly, the geographical areas were introduced, these are the oceans, seas, rivers, or canals where the ports and anchorages are located.
- Fourth and lastly, the characteristics of the water in each port or anchorage that could affect the survival of the species transferred as fouling were identified.

Once the data from the trips were obtained, we proceeded to search for invasive species through the online database Global Invasive Species Database, hereinafter GISD (http://www.iucngisd.org/gisd/). This website aims to increase public awareness of invasive species and facilitate effective prevention activities by disseminating the knowledge and expertise of specialists to a wide global audience (GISD, 2022). It focuses on invasive alien species, which are considered much more dangerous than non-invasive species as they threaten native diversity and natural areas by having a high capacity to adapt and survive in different environments. To perform this search, the GISD work option by filters was used, defined below in the Table 1. As many searches were made as ports visited by the vessel during the voyages, modifying the location in each one of them. The location filter corresponds to the ports or geographical regions that the vessel visits since the last departure to the shipyard. They try to be as specific as possible, but sometimes the GISD database does not have the specific port filter, so it is extended to the region.

Table 1: Filter selection on GISD.

Taxonomy	Animalia Plantae
Localización	The location of the port in question will be marked. If we do not have th option, we will mark one or several nearby ports that bring us closer to t place. We could also mark by seas or rivers as long as the area is not too distant from the port, since species that do not belong to the area we are interested in could appear.
System	Marine Marine / freshwater / brackish
Pathway	Transport-stowaway: ship/boat hull fouling

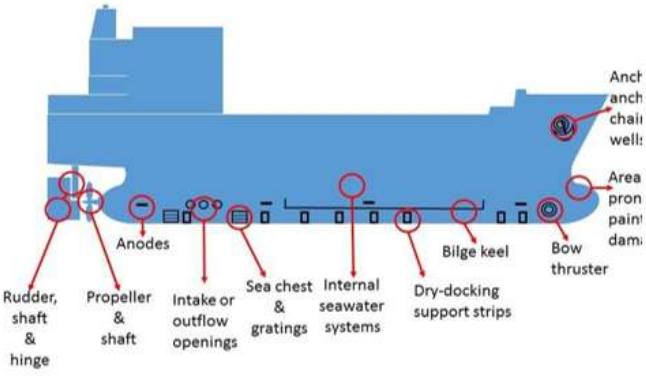
Source: Authors.

Once the search is done, each species found, and the location is recorded in an Excel table and then plotted on a map using the QGIS geographic information system (https://www.qgis-.org/en/site/). QGIS is an open-source Geographic Information System that allows you to create maps to visualize, manage and analyze data in a more simplified way.

2.3. Hull areas most affected by biofouling.

While the vessel is in dry dock, photographs of the hull are taken to evaluate its condition in terms of the fouling it shows. All areas of the hull in contact with the water are looked at, including the side, bow, stern, propeller, etc., searching for the parts where the organisms have adhered in greater quantities. In addition, the niche areas of the ship where these organisms are found were identified, knowing that those most susceptible to their accumulation are usually the ones represented in the Figure 4.

Figure 4: Niche areas of the ship susceptible to IAS accumulation.



Source: Georgiades and Kluza, 2020.

3. Results and discussions.

3.1. Invasive species prediction attached to the hull.

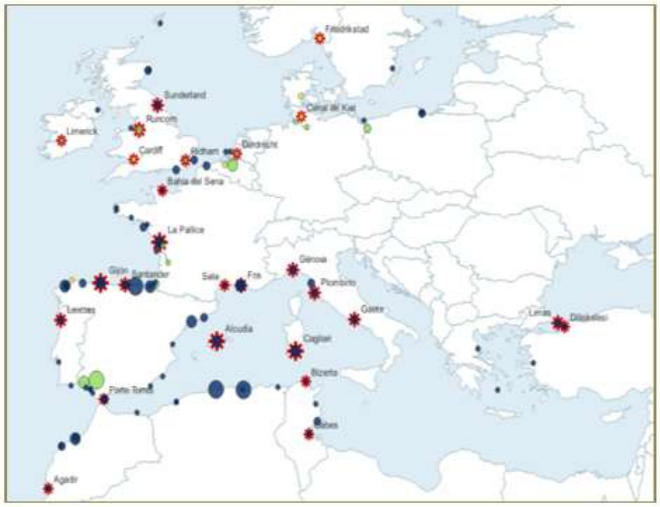
The vessel under study called at 80 ports of which 11 are freshwater, 9 are brackish water and the rest are saltwater. The map in the Figure 5 shows all of them, and these ports are mainly centered in areas of the Mediterranean Sea, North Atlantic, Cantabrian Sea and North Sea, passing through narrow channels such as the Kiel Canal. The passage through this channel is relevant for the research, due to its shallowness, narrowness, number of species detected and intense maritime traffic, which causes long waits for vessels wishing to cross it.

Species do not automatically adhere to the hull while the ship is sailing but need to be kept static for a period, either at berth or at anchor. Therefore, long waits at the entrance of the harbor also make possible the adhesion of the species in the area to the hull structure. In relation to the total time of the study, the vessel spends almost a tenth of the time at anchor and more than a quarter of the time at berth.

Also in the Figure 5 are highlighted in red those ports where some of the invasive species were found after searching through the GISD database.

Although it does not sail around the globe, there are enormous distances between some of the ports visited, so it suffers very different characteristics of temperature, salinity, PH, depth, sea currents and other variables that influence the survival of the fouling. For example, one of the trips has been from the port of Agadir in Morocco to Szcecin in Poland, passing through the Kiel Canal. This is an example of a long voyage in which the vessel has sailed in very particular waters that make up habitats of different characteristics. In the map of the Figure 5 the salinity of each port is differentiated into salty, fresh, and brackish depending on whether they are represented by blue, green, or yellow circles, respectively.

Figure 5: Distribution of the ports visited by the ship. Circles in blue: salty, in green: fresh, in yellow: brackish and with a red star: where IAS were detected.



Source: Authors.

The species from different areas may not survive due to the changing characteristics of the environment, which may not be suitable for their development. These habitats are distinguished by the salt content, depth, or temperature of the particular geographical area.

After searching the GISD database by applying the filters mentioned in the methodology section, 15 invasive species were found that may come from the 80 ports where the ship calls. One third of those ports were identified with invasive species. The Table 2 summarizes all the species found, specifying the area and the port from which they may come.

Table 2: IAS detected by zone and port of origin.

IAS	Zone	Port
Styela clava	North Atlantic	La Pallice
	Cantabrian Sea	Leixoes
		Gijón
		Santander
	Mancha Canal	Sena Bay
	Bristol Canal	Cardiff
	Támesis River	Ridham
	Mersey River	Runcorn
Codium fragile ssp. Tomentosoides	North Sea	Sunderland
	Mediterranean Sea	Alcudia
		Bizerta
		Gabes
		Fos
	Bristol Canal	Cardiff
	Oude Mass River	Dordrecht
	Shannon River	Limerick
	Mersey River	Runcorn
Crassostrea gigas	North Atlantic	Agadir
	Mediterranean Sea	Bizerta
		Gabes
	Bristol Canal	Cardiff
	Mersey River	Runcorn
	North Sea	Sunderland
Alitta succinea	Mediterranean Sea	Cagliari
		Porto Torres
	Kiel Canal	Kiel Canal
Sabella spallanzanii	North Atlantic	Agadir
	Mediterranean Sea	Bizerta
		Gabes
Rapana venosa	Marmara Sea	Diliskelesi
		Limas
	North Sea	Sunderland
Gracilaria vermiculophylla	North Atlantic	Agadir
	North Sea	Sunderland
Mytilusgalloprovincialis	Mediterranean Sea	Bizerta
		Gabes
Caulerpa taxifolia	Mediterranean Sea	Génova
		Piombino
Mya arenaria	North Sea	Sunderland
	Kiel Canal	Kiel Canal
Ascidiella aspersa	Mancha Canal	Sena Bay
Dreissena polymorpha	Kiel Canal	Kiel Canal
Polysiphonia brodiei	North Atlantic	Agadir
Bugula neritina	Mediterranean Sea	Gaeta
Musculista senhousia	Mediterranean Sea	Sete

Source: Authors.

3.2. Hull areas most affected by biofouling.

As soon as the vessel arrives in dry dock, photographs are taken to evaluate its condition in relation to the fouling. The effect caused by the friction of the water during navigation on the incrusted species is considered, which causes them to detach from the surface by themselves. The higher the speed of the ship, the greater the frictional force on the hull surface. Actually, the surface of the hull is not completely flat and homogeneous but presents certain uniformities where the friction does not affect with such force as to detach the encrusted organisms, these are the so-called niche areas.

As an example of this, one of the ship's sacrificial anodes can be seen in the image in the Figure 6. This system is used to prevent corrosion in the submerged part of the hull. Due to the low water flow between the anode and the surface of the hull, the species are able to remain adhered in that area, since there is much less friction as the hull is protected by the anode. The same figure also shows the ballast water outlet surrounded by fouling due to the deterioration of the antifouling film by the friction exerted by the water during discharge.

Figure 6: Picture of a sacrificial anode and water intake of the vessel.

Source: Authors.

The hull has a balance keel along both sides, as shown in the image of the Figure 7, in order to reduce the rolling movement during navigation. Only moss and minor algae encrustations can be detected on the outside of the hull. However, in its inner part, since there is not enough friction to remove the species that have adhered, a larger number of incrustations can be detected.

Figure 7: Balance keel of the vessel. The image above is the outer part, and the image below is the inner part of the keel.

Source: Authors.

Lastly, the Figure 8 shows the aft area of the hull corresponding to the area most affected by fouling. In particular, the propeller is where the largest size and quantity of fouling is located in the entire hull, since it is easier for the species to remain adhered as it is not so affected by the friction of the water. The figure shows in detail the parts with the greatest accumulation of organisms, such as the piece behind the propeller, called cone, where the larger species accumulate due to the hydrodynamic action of the propeller. In the same way, the core and the roots of the blades also have a large accumulation of species. The propeller is affected by the cavitation phenomenon reflected in the outer edges of the blades. This effect caused by the explosion of tiny air bubbles corrodes this area leaving it completely smooth and free of incrustations.

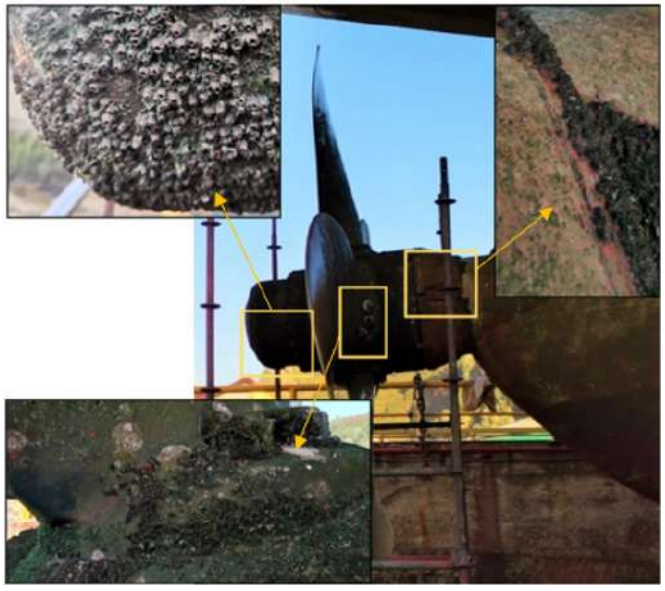
The upper right of the Figure 8 shows another of the most affected areas both at the stern and along the side. This is the welded joint between the hull plates, which forms a roughness where the species manage to wedge in and remain attached, sheltered from any force that could dislodge them.

Despite all the time the vessel has been in the water, in general terms the hull does not present a large amount of foul-

ing. This is associated with the navigation between different geographical areas and the variation in salinity that may have caused incompatibilities for the life of the species causing their disconnection with the surface of the hull. Even so, as explained from the photographs, the following areas of the hull are defined as the most likely to be affected by biofouling:

- Rudder blade,
- Propeller,
- Propeller shaft,
- Union between the welded parts of the hull,
- Inner part of the stabilizer fin,
- Cathodic protection anodes, and
- Seawater intakes.

Figure 8: Biofouling on the ship's propeller. Upper left image: cone, upper right image: junction of the parts, lower image: core of the blade.



Source: Authors.

Conclusions

In the research, we have predicted the invasive species that have been able to adhere to the ship according to its voyages, in addition to assessing the condition of the hull for fouling once it arrives at the shipyard and the parts of it most affected.

The survival of the species attached to the hull are affected during the operation of the vessel for two reasons; one is due to the itinerary of the vessel and the passage through waters of different characteristics and the other is due to the effect of the friction of the water against the hull during navigation. Although the vessel's voyages are not global in scope and are centered in Europe and North Africa, changes in the characteristics of the water are recognized throughout its voyage, which affects the life of the species, causing them to detach from the hull by themselves. However, after searching for invasive species present in each port of call, some of them are found in both saltwater and freshwater ports. Throughout the voyages, IAS are detected in more than 30% of the ports, where the species have had the opportunity to adhere to the ship's structure to be transferred to new locations. The species that survive long journeys are more likely to survive in the new environment and displace the native species, so special care must be taken with them.

The condition of the ship's hull once it arrives at the shipyard after all its time afloat may be dirty but not particularly affected by fouling. The water friction has affected the hull in such a way that during navigation they are detached by themselves, especially in the bow part. The greatest accumulation of fouling is found in the niche areas and in the aft part of the hull where the propeller is located. These are areas where, due to lack of maintenance or due to the operational design of the hull itself, it may be easier for the antifouling paint to be missing at some point and allow the adhesion of species. The propeller is where the greatest number and size of fouling is detected because it is where the water friction has the least effect.

This accumulation of organisms also leads to lower performance in the ship's propulsion equipment, increasing fuel consumption by requiring more power to reach the required speed, and we consider that further study of this is required. The hulls must be treated by applying antifouling paints and cleaning them from time to time, so that the operation of the ship is not so affected by the loss of speed caused by fouling, in addition to reducing the impact of biological contamination.

It is necessary on the part of international organizations the publication of mandatory regulations for the control of invasive species through fouling. The non-mandatory recommendations already published (International Maritime Organization, 2011) should be implemented as mandatory, just as the BWM Convention (International Maritime Organization, 2017) was done since most of the time the recommendations are not applied by those responsible.

Acknowledgements.

It is appreciated to the Avilés's shipyard and the ship in drydock whose let us enter and being able to collect all data and samples for the study.

References.

Amara, I., Miled, W., Slama, R.B., Ladhari, N., 2018. Antifouling processes and toxicity effects of antifouling paints on marine environment. A review. Environ Toxicol Pharmacol 57, 115–130. https://doi.org/10.1016/j.etap.2017.12.001.

Ashton, G.V., Davidson, I.C., Geller, J., Ruiz, G.M., 2016. Disentangling the biogeography of ship biofouling: barnacles in the Northeast Pacific. Global Ecology and Biogeography 25, 739–750. https://doi.org/10.1111/geb.12450.

Aviles Port, 2023. Port Authority of Aviles URL https://www.puertoaviles.es/es/portada.asp (accessed 9.1.23).

Boletín Oficial del Estado del Gobierno de España, 2007. Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad.

Castellanos-Galindo, G.A., Robertson, D.R., Sharpe, D.M.T., Torchin, M.E., 2020. A new wave of marine fish invasions through the Panama and Suez canals. Nat Ecol Evol 4, 1444–1446. https://doi.org/10.1038/s41559-020-01301-2.

CBD, 2023. Home. Convention on Biological Diversity. URL https://www.cbd.int/ (accessed 9.21.23).

Cebrian, E., Francour, P., Galil, B., Otero, M. del M., Savini, D., 2013. Monitoring of marine invasive species in Marine Protected Areas (MPAs) in the Mediterranean : strategy and practical guide for managers. IUCN.

Coughlan, N.E., Walsh, D.A., Caffrey, J.M., Davis, E., Lucy, F.E., Cuthbert, R.N., Dick, J.T.A., 2018. Cold as ice: a novel eradication and control method for invasive Asian clam, Corbicula fluminea, using pelleted dry ice. Management of Biological Invasions 9, 463–474.

Dafforn, K.A., Lewis, J.A., Johnston, E.L., 2011. Antifouling strategies: History and regulation, ecological impacts and mitigation. Marine Pollution Bulletin 62, 453–465. https://doi.org/10.1016/j.marpolbul.2011.01.012.

Davidson, I., Brown, C., Sytsma, M., Ruiz, G., 2009. The role of containerships as transfer mechanisms of marine biofouling species. Biofouling 25, 645–55. https://doi.org/10.1080/08927010903046268.

Davidson, I., Scianni, C., Hewitt, C., Everett, R., Holm, E., Tamburri, M., Ruiz, G., 2016. Mini-review: Assessing the drivers of ship biofouling management–aligning industry and biosecurity goals. Biofouling 32, 411–428. https://doi.org/10.1080/08927014.2016.1149572.

Durán, C., 2011. Estimation of the costs of the zebra mussel invasion in the Ebro basin.

Galil, B.S., Boero, F., Campbell, M.L., Carlton, J.T., Cook, E., Fraschetti, S., Gollasch, S., Hewitt, C.L., Jelmert, A., Macpherson, E., Marchini, A., McKenzie, C., Minchin, D., Occhipinti-Ambrogi, A., Ojaveer, H., Olenin, S., Piraino, S., Ruiz, G.M., 2015. 'Double trouble': the expansion of the Suez Canal and marine bioinvasions in the Mediterranean Sea. Biol Invasions 17, 973–976. https://doi.org/10.1007/s10530-014-0778-y.

Georgiades, E., Kluza, D., 2020. Conduct of in-water biofouling surveys for domestic vessels.

GISD, 2022. GISD. URL http://www.iucngisd.org/gisd/about.php (accessed 10.19.22).

Globallast Partnerships, 2017. Globallast Partnerships - Building Partnerships to Assist Developing Countries to Reduce the Transfer of Harmful Aquatic Organisms in Ships' Ballast Water. GloBallast. URL https://archive.iwlearn.net/globallast.imo.org/index.html (accessed 10.31.23).

Iacarella, J.C., Burke, L., Davidson, I.C., DiBacco, C., Therriault, T.W., Dunham, A., 2020. Unwanted networks: Vessel traffic heightens the risk of invasions in marine protected areas. Biological Conservation 245, 108553. https://doi.org/10.1016/j.biocon.2020.108553.

Iberdrola, 2022. How do invasive alien species impact biodiversity?. URL https://www.iberdrola.com/sostenibilidad/especies-invasoras (accessed 11.30.22).International Maritime Organization, 2022. Biofouling URL https://www.imo.org/es/OurWork/Environment/Pages/Biofouling.aspx (accessed 10.28.22).

International Maritime Organization, 2019. Guidelines for the Assessment of the National Legal and Social Status of Ballast Water 33.

International Maritime Organization, 2017. Ballast water management. URL https://www.imo.org/es/OurWork/Environment/Paginas/BallastWaterManagement.aspx (accessed 10.25.22).

International Maritime Organization, 2011. Guidelines for the control and management of ship´s biofouling to minimize the transfer of Invasive Aquatic Species.

International Maritime Organization, 2004. Summary of Ballast Water Management URL: https://www.imo.org/en/OurWork/Environment/Pages/BallastWaterManagement.aspx (accessed 9.26.22).

International Maritime Organization, 2001. International Convention on the Control of Harmul Anti-fouling Systems on Ships. URL: https://www.imo.org/es/About/Conventions/Pages/-International-Convention-on-the-Control-of-Harmful-Anti-fouling-Systems-on-Ships-%28AFS%29.aspx (accessed 11.30.22).

Kenworthy, J.M., Rolland, G., Samadi, S., Lejeusne, C., 2018. Local variation within marinas: Effects of pollutants and implications for invasive species. Marine Pollution Bulletin 133, 96–106. https://doi.org/10.1016/j.marpolbul.2018.05.001.

Ministerio para la transición Ecológica y el Reto Demográfico Gobierno de España, 2013. Catálogo Español de Especies Exóticas Invasoras. URL https://www.miteco.gob.es/es/biodiversidad/temas/conservacion-de-especies/especies-exoticas-invasoras-/ce-eei-catalogo.aspx (accessed 4.4.23).

MITECO, 2022. Alien Species to concern for the European Union. URL https://www.miteco.gob.es/es/biodiversidad/temas/-conservacion-de-especies/especies-exoticas-invasoras/ce-eei-lista-UE-listado.aspx (accessed 10.9.22).

Montes Coto, H., 2009. Hydrodynamics and drag.

Ojaveer, H., Olenin, S., Narščius, A., Florin, A.-B., Ezhova, E., Gollasch, S., Jensen, K.R., Lehtiniemi, M., Minchin, D., Normant-Saremba, M., Strāke, S., 2017. Dynamics of biological invasions and pathways over time: a case study of a temperate coastal sea. Biological Invasions 19, 799–813. https://doi.org/10.1007/s10530-016-1316-x.

Perez, L., Chica Moreu, C., 2006. Estimación de los costes económicos de la invasión del mejillón cebra (Dreissena polymorpha) en la Cuenca del Ebro. Documento de trabajo - Fundación Economía Aragonesa (FUNDEAR), ISSN 1696-2125, No. 35, 2006, pags. 1-48.

Pérez, M.C., 2012. Biological fouling and methodology for its control.

Schultz, M.P., 2007. Effects of coating roughness and biofouling on ship resistance and powering. Biofouling 23, 331–341. https://doi.org/10.1080/08927010701461974.

Sharma, D.C., 2006. Ports in a Storm. Environmental Health Perspectives 114, A222–A231. https://doi.org/10.1289/ehp.114-a222.

Tsiamis, K., Azzurro, E., Bariche, M., Çinar, M.E., Crocetta, F., De Clerck, O., Galil, B., Gómez, F., Hoffman, R., Jensen, K.R., Kamburska, L., Langeneck, J., Langer, M.R., Levitt-Barmats, Y., Lezzi, M., Marchini, A., Occhipinti-Ambrogi, A., Ojaveer, H., Piraino, S., Shenkar, N., Yankova, M., Zenetos, A., Žuljević, A., Cardoso, A.C., 2020. Prioritizing marine invasive alien species in the European Union through horizon scanning. Aquatic Conserv: Mar Freshw Ecosyst 30, 794–845. https://doi.org/10.1002/aqc.3267.

Ulman, A., Ferrario, J., Forcada, A., Seebens, H., Arvanitidis, C., Occhipinti-Ambrogi, A., Marchini, A., 2019. Alien species spreading via biofouling on recreational vessels in the Mediterranean Sea. Journal of Applied Ecology 56, 2620–2629. https://doi.org/10.1111/1365-2664.13502.

UNCTAD, 2021. Maritime Transport Review.

Williams, S.L., Davidson, I.C., Pasari, J.R., Ashton, G.V., Carlton, J.T., Crafton, R.E., Fontana, R.E., Grosholz, E.D., Miller, A.W., Ruiz, G.M., Zabin, C.J., 2013. Managing Multiple Vectors for Marine Invasions in an Increasingly Connected World. Bioscience 63, 952–966. https://doi.org/10.1525/bio.2013.63.12.8.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 172–177

ISSN: 1697-4840, www.jmr.unican.es

Automatic Conveyor With Black and White Color Sensor for Vessel Cargo Selection

Darul Prayogo[1,*], Muhamad Shofiyudin[2]

ARTICLE INFO

Article history:
Received 10 Aug 2023;
in revised from 24 Aug 2023;
accepted 16 Sep 2023.

Keywords:
Automatic Conveyor, color Sensor, Arduino Nano, Microcontroller, Efficiency.

ABSTRACT

Electronic components were developed in modern life to help alleviate human work. One application is in sorting goods using conveyors. A conveyor is a device used to move an object from one place to another by a mechanical system. In the industrial world, to transport goods, many use conveyors because of the large and sustainable number of goods. In industries involving large and heavy goods, it is needed to apply conveyors. Various tools that use control systems can reduce human roles even without human assistance. Such a control system is applied to a conveyor so that the conveyor can operate auto-run. The method used in this research is to make a prototype, the manufacturer; this prototype is developing a new product or perfecting an existing product, be it hardware or software. The automatic conveyor proto e utilizes the project board for the control system assembly, arduino nano as an Arduinontroller, and some sensors as a supporting automation component. Researchers use this method to research and develop arduino nano software starting from analysis, design, code, and testing. The data collected in this study uses an observation checklist, then the data is processed to move the conveyor with the software that has been created. Microcontrollers are programmed using the Arduino IDE programming application. Through this research, it is expected that sorting of goods can be done 24 hours, has high efficiency, reduces electricity costs and reduces human power for vessel cargo selection..

1. Introduction.

Moving goods can be done in a variety of ways. The era of globalization supports science and technology in all areas of life. Various forms of technological facilities in science, industry, offices, and even in everyday life, especially on ships. The development of technology significantly affects human life, both from lifestyle and work. (Díaz-García et al., 2017). Creating tools that can sort shiploads into the best alternative to facilitate human work.

Many professions make people work hard by relying on physical strength. (Salam et al., 2011), Human work is getting lighter by utilizing technology because tools help many. This makes the industrial world take advantage of technological developments, which used to work manually now. No, watching auxiliary aircraft that work automatically will undoubtedly save energy. One of the tools that humans have made is a conveyor; it has many types, one of which is a conveyor that uses a belt or often called a belt conveyor. Bela t conveyor is an auxiliary aircraft whose function is to move objects above the belt (Selvan et al., 2019).

The conveyor is one of the devices that can facilitate the transfer of goods/cargo such as factories/industries, ports, airports, and others. (Selvan et al., 2019). The conveyor is generally a conveyor that operates manually; this tool uses continuously since the system is turned on, there are objects detected, or nothing are seen on it. With the conveyor constantly working

[1]Politeknik Ilmu Pelayaran Semarang. Tel. (024) 8311527. E-mail Address: darul@pip-semarang.ac.id.

[2]Politeknik Ilmu Pelayaran Semarang. Tel. (024) 8311527. E-mail Address: shofiyudin@pip-semarang.ac.id.

[*]Corresponding author: Darul Prayogo. E-mail Address: darul@pip-semarang.ac.id.

without depending on the existence of the Object, there are disadvantages, especially the use of electrical energy that is less effective. In addition, undeveloped conveyors have not been able to sort the color of the Object automatically, so if the conveyor transports the color of the different thing, it still requires additional power to sort it out.

However, manual conveyors are still widely used in all wasteful electrical energy fields because they work continuously. (Sun & Böhringer, 2020). Existing manual conveyors can be modified/ added to reduce the use of electrical energy that costs more expensive. Furthermore, the proper sensor for this conveyor can help put humans at work because it can sort, distinguish colors and manage the conveyor's working time.

A conveyor is a device used to move an object from one place to another by a mechanical system. In the world of industrial, to transport goods many use conveyors, because of the large and sustainable number of goods. In industries involving many large and heavy goods, it is needed to apply conveyors. There are several types of conveyors that are created (belt conveyor, roller conveyor, chain conveyor, bucket conveyor, screw conveyors, pneumatic conveyor) and used according to the needs of various different industries. Under certain conditions, the use of conveyors is more efficient compared to other conveyors; conveyors can mobilize large quantities of goods continuously from one place to another. (Jin et al., 2018).

In this study, researchers chose the belt conveyor as a tool used as a research object because of the simple conveyor work system. (Jin et al., 2018). A belt conveyor is a means of transportation that utilizes tires or rubber as a moving belt to carry the material that is on it.

The working principle of the belt conveyor is to carry the material or object that is above the belt, where the belt is moved because the head pulley is rotated by the motor through the gear reducer.(Pham et al., 2006)

This research utilizes electronic components; some of the essential elements of electronics in this study are microcontrollers and sensors. A microcontroller is an IC chip (Integrated Circuit) that is able to receive input signals, process them and send output signals in accordance with the program filled into them. The input signal comes from a sensor that is information from the environment to be processed microcontroller. In contrast, the output signal is addressed to the actuator that can affect the environment. A microcontroller is the brain of a device capable of interacting with the environment with the help of supporting components. Basically, a microcontroller is a computer in one chip, which contains a microprocessor, memory, Input / Output (I / O), and other supporting components. The speed of data processing in microcontrollers is lower when compared to personal computers (PCs). The rate of microprocessors on PCs has reached the GHz order, while the operating speed of microcontrollers generally ranges from 1 - 16 MHz. So is the capacity of RAM and ROM on PCs that can reach the Gbyte / Tbyte order, in contrast to microcontrollers that only range bytes / Kbyte. (Crepaldi et al., 2021).

The microcontroller used in Arduino nano.(Yaseen et al., 2021). Arduino Nano is one of the small microcontroller development boards. (Pan & Pan, 2019), It can be used on project boards. This microcontroller was created using the atmega328 base. (Aghenta & Iqbal, 2019) for version 3.x and Atmega 168 for version 2.x (Ramos-cosi & Vargas-cuentas, 2021). Because the Arduino Nano is mini-sized, it is only equipped with USB pins and plugs that are used to connect to the computer and are not equipped with direct electric current plugs. To provide power to the microcontroller, this can be done by connecting the power supply with the pin on the Arduino board (Kelechi et al., 2021).

This research aims to develop conveyors by incorporating electronic elements, namely microcontrollers, motion sensors, and color sensors, to work effectively and efficiently. Utilizing this is expected to create a belt conveyor that can operate automatically. This research is necessary because it can help facilitate human work by utilizing project boards to put electronic components as props. Using these sensors, the conveyor will only work when the Object is exposed and will automatically sort the Object's color. In addition, this study can reduce the use of electricity because the conveyor will work if there are objects above the belt.

2. Methodology.

The development of conveyors is carried out by combining electronic science. (Jin et al., 2018), This is done by using the Arduino nano project board as a microcontroller and some sensors as support devices. The method used by researchers is the creation of prototypes (Ramos-cosi & Vargas-cuentas, 2021). Researchers used this method to research and develop Arduino nano Software. (Amirah et al., 2020) Starting from analysis, design, design, software coding, and testing. The data collected in this study uses an observation checklist, then the data is processed to move the conveyor with the software that has been created. This research develops a product and will produce a new product or perfect an existing product. (Taques et al., 2021). In this case, it was designed with software, operating systems, and applications.

3. Results.

3.1. Assembly.

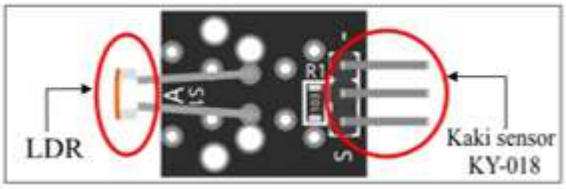
This study will combine the mechanical design of the conveyor (Selvan et al., 2019) with electronic components. To drive rollers and sorters, the designer automatically utilizes sensors and microcontrollers and uses the project board as the basis for designing electronic schemes. The two primary sensors used are ky-018 and TCRT-5000.

The main component of this KY-018 sensor module is the LDR (Light Dependent Resistor), so this component works depending on the intensity of the light. (Moeys et al., 2018) exposed. The working principle of this component is that if the light is exposed to high intensity, the LDR resistance will decrease; conversely, if the light is dim, the LDR resistance will rise. The LDR will be a poor conductor or a great resistance when the light is dimmed.(Leeuw & Boss, 2018), And the LDR will be a good conductor or small resistance when exposed to

high-intensity light. This study used the LDR sensor as an object detection sensor by combining lasers as light-spreaders. (Jeong et al., 2019).

The ky-018 sensor will operate well when it gets a voltage of 3.5V to 5V; this sensor can provide digital and analog input signals to connected microcontrollers.

Figure 1: KY-018 sensor.



Source: Authors.

There are three legs on this sensor module, the coded foot (-) is for VDC(-), the middle foot is for VDC(+), and the coded foot (S) for the input signal to be forwarded to the microcontroller (Tahir et al., 2022).

The following sensor used in this study is the TCRT-5000 Type Black and White sensor has two essential parts: the infrared transmitter as a transmitter and the receiver as a reflection receiver. The working principle is that the transmitter emits infrared. If it is blocked by a white or reflective object, then the infrared will be reflected and detected by the receiver, then this sensor can be used as an object detector between black and white.

Figure 2: Front view of the TCRT-5000 sensor.

Source: Authors.

The TCRT-5000 sensor operates well when it gets a voltage source of 5Volt to 7Volt. These sensors only provide digital input signals. There are four legs on the TCRT-5000 sensor module, the coded foot (VCC) is the foot that serves to get the voltage VDC (+), the coded foot (GND) is the foot for the ground or VDC (-), the foot that has code (D0) and (A0) for the input signal to be forwarded to the microcontroller.

Figure 3: Rearview of the TCRT-5000 sensor.

Source: Authors.

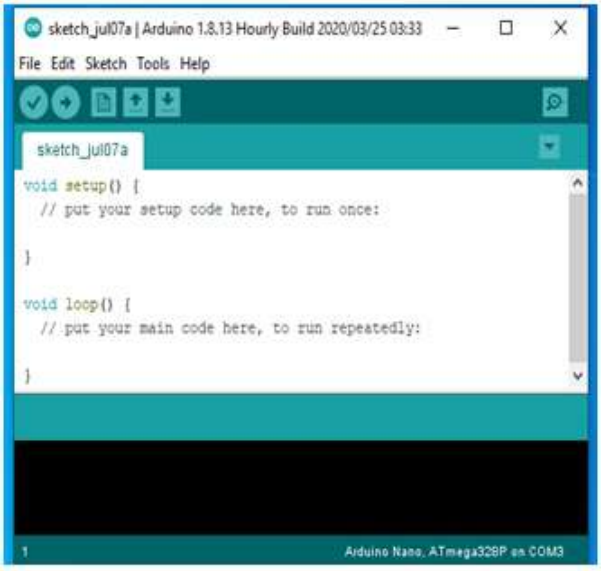
On the back of the sensor module, TCRT-5000 equipped with variable resistors serves to regulate the sensitivity of the receiver (Bian et al., 2021) in capturing infrared reflections emitted by the transmitter so that the effective detection distance can be adjusted.

3.2. Creation of Software Automatic Conveyor Control System Detection of Object Presence and Color objects (Black and White).

Programming processor using a computer (Borys et al., 2020) means. This study used Arduino nano as a microcontroller (Khanna et al., 2021). Arduino has a particular application for programming, namely Arduino Integrated Development Environment or often called Arduino IDE (Kumar et al., 2022).

To program, Arduino must be installed Arduino IDE application (Kumar et al., 2022) the computer to be used to program. This application can be downloaded from various sources on the internet, including on the official Arduino page (Selvaraj & Anusha, 2021).

Figure 4: The initial view of Arduino IDE.



Source: Authors.

If the microcontroller is connected, it is ready to be programmed according to the designer's expectations. For example, here is the program or coding used in automatic conveyor drilling with black and white and object detection sensors (Kelechi et al., 2021).

3.3. Prototype Trials.

The research results on the development of automatic conveyors with some of these sensors, test the sensors used and get mixed results. Researchers tested the sensor by giving the sensor's criteria and observing the reactions that occurred due to the action. The result of creating this automatic conveyor development model is that the conveyor belt drive machine can operate automatically when placed objects on it, and servo motors can sort mechanical things based on the Object's color.

Figure 5: Coding Arduino IDE.

Source: Authors.

Design of automated conveyor development model props (Jin et al., 2018) This is done in sequence in each manufacturing process and adjusted to the problem formulation. The manufacturing process is done well and in detail to get the designer's expected results.

Automatic Conveyor Development Model Show Making (Jin et al., 2018) With Color Sensor and Object Presence Detection Sensor. The initial part of making a prop is to prepare the tools and materials to be used because the completeness of tools and materials will affect the smooth manufacture of braces.

This stage of making props further makes the conveyor design first, to make it easier for the designer to make conveyor material parts. In the manufacture of conveyor design, the designer creates a sket in a manual image.

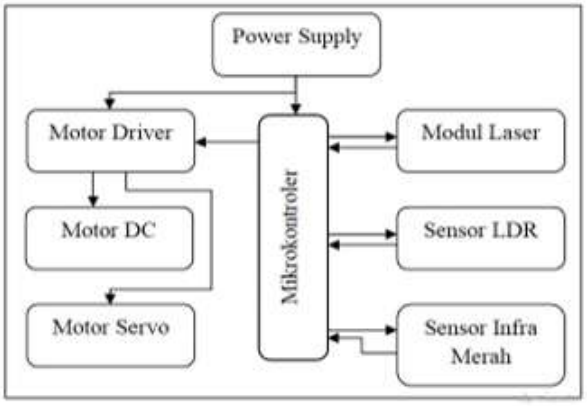
The materials to be used should also be considered based on their advantages and disadvantages, function, durability, and aesthetic value. Designers use clear acrylic as the most widely used material.

The parts of the props are made manually, so it requires thoroughness to get results in line with expectations. The details are designed into an amount in a mechanical form that will be combined with electronic elements, and corrections and repairs are made if there are parts that are not perfect. Design of Automatic Conveyor Control System Detection of Object Presence and Color

The electronic control system is converting a signal into another signal to give the desired system response; the simple electronic system is input, process, output.

Electronic components cannot operate on their own. (Aghenta & Iqbal, 2019), Between components must be interconnected to operate properly because between components with other components have their respective functions; for that, the designer must create a scheme before assembling these components.

Figure 6: Control system schema.



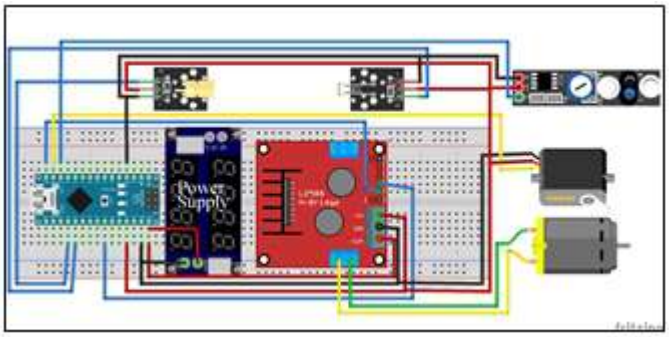
Source: Authors.

This assembly utilizes the project board as the primary assembly board. Arduino Nano as a microcontroller, motor driver as dc motor rotation controller, KY-018 as object detection LDR sensor assisted by KY-008 laser module, TCRT-5000 as black and white detection sensor, DC motor as roller drive, servo motor as a black and white sorter, and some supporting components.

4. Discussion.

The Creation of the Automatic Conveyor Development Model Show With Color Sensor and Object Presence Detection Sensor proved to help alleviate human work (Management et al., 2020). It can be applied in the industrial world. Its existence is better than a manual conveyor that works continuously despite no charge/workpiece. This research can save the

Figure 7: Wire control system diagram.



Source: Authors.

burden of electricity costs and reduce machine working hours so that it is expected that the machine can work longer and be more durable. For industries that already have conveyors, manual conveyors that already exist today can be added using this software, so there is no need to buy new tools.

Design of automatic conveyor control system (Selvan et al., 2019) It uses two sensors, the TCRT-5000 black and white sensor and the KY-018 type object detection sensor connected to the Arduino Nano microcontroller, both of these sensors can provide input signals in digital form that are passed to the microcontroller. What distinguishes these two sensors is the working principle; the TCRT sensor works because the receiver receives the reflection of infrared light emitted by the transmitter, while the KY-018 sensor works based on the intensity of the morning (Moeys et al., 2018).

Ky-018 and TCRT-5000 sensors have the disadvantage of not functioning correctly if both sensors detect objects and colors together. Because in one programmatic microcontroller, each sensor must provide a sequence input signal according to coding (Borys et al., 2020).

The next drawback is that the black and white sensor will experience dysfunction if it operates after the object detection sensor. For example, if the KY-018 sensor has detected the presence of an object and after that, the TCRT-5000 sensor detects black and white, then the TCRT-5000 sensor will experience dysfunction and will not be able to scatter between black and white.

KY-018 sensors, TCRT-5000 sensors, and Arduino microcontrollers are commonly used components in robotics; in addition to being easy to obtain, such details are easy to design and program because KY-018, TCRT-5000, and Arduino microcontrollers are complex modules. (Borys et al., 2020).

Automatic Conveyor Control System Programming Detection of Object Presence and Color.

A pre-programmed microcontroller controls this object and color detection system (Kelechi et al., 2021). Programming applications using Arduino IDE (Murad et al., 2021). The designer chose the application because it has the most straightforward programming language compared to other programming applications, so it is easy to use and easy to understand.

In a coding is written microcontroller functions process input signals to produce output signals(Taques et al., 2021), For example, the input signal from the KY-018 sensor will have an output signal in the form of a DC motor rotation. (Moeys et al., 2018). Coding on microcontrollers will run sequentially as written, which has been explained in the results of the study. So the microcontroller will not respond to the input signals of all sensors before completing the previous function. This is the disadvantage of programming an automatic conveyor control system.

Microcontrollers have been programmed in sequence (TCRT-5000 sensor detects color, KY-018 sensor detects object DC motor conveyor drive operates, Motor servo operates Object carried by conveyor belt, object split by servo motor Object falls pointed or left according to color). If the Object has not been lost and has been given the next thing, then the conveyor will not respond to the presence of the item. So one process can only be given one thing.

In the application of use, the selection of the suitable sensor can be adjusted for a wide variety of conveyors; in advanced industries, sensors can be developed and can read more color code, code, or motion more efficacy. But this study is limited to using only object detection sensors to move the conveyor only and black and white detection sensors only.

Conclusions

The creation of this automatic conveyor development model demonstrates a mechanical conveyor prototype to detect the presence of objects and colors. Use Arduino microcontroller, black and white TCRT-5000 sensor, and KY-018 object detection sensor. Aiming for both sensors to operate correctly then the TCRT-5000 sensor is placed front before the KY-018 sensor.

Creating the Automatic Conveyor Development Model demonstrates proven to increase efficiency and can be applied real with size and dimensions suitable for industry needs. Its existence is better than a manual conveyor that works continuously even though there is no workpiece. With this research, it can save the burden of electricity costs and reduce machine working hours so that it is expected that the machine can work longer and be more durable. These automatic conveyor props can be further developed by adding more color sensors such as red, yellow, and green color sensors or barcodes to be made in the form of real conveyors and utilized in the industrial maritime.

References.

Aghenta, L. O., & Iqbal, M. T. (2019). *Low-Cost, Open Source IoT-Based SCADA System Design Using Thinger . IO and ESP32 Thing*. 1–24. https://doi.org/10.3390/electronics80-80822.

Amirah, N., Jamil, A., Jumaat, S. A., Salimin, S., Abdullah, M. N., Fateh, A., & Nor, M. (2020). *Performance enhancement of solar powered floating photovoltaic system using arduino approach*. *11*(2), 651–657. https://doi.org/10.11591/ijpeds.v11.i2-.pp651-657.

Bian, Y., Chen, X., Cao, H., Xie, D., Zhu, M., Yuan, N., Lu, L., Lu, B., Wu, C., Bahaji Azami, N. L., Wang, Z., Wang, H.,

Zhang, Y., Li, K., Ye, G., & Sun, M. (2021). A correlational study of Weifuchun and its clinical effect on intestinal flora in precancerous lesions of gastric cancer. *Chinese Medicine (United Kingdom)*, *16*(1), 1–13. https://doi.org/10.1186/s13020-021-00529-9.

Borys, S., Kaczmarek, W., & Laskowski, D. (2020). *Selection and Optimization of the Parameters of the Robotized Packaging Process of One Type of Product*. 1–21. https://doi.org/10.3390/s20185378.

Crepaldi, M., Merello, A., & Di Salvo, M. (2021). A multi-one instruction set computer for microcontroller applications. *IEEE Access*, *9*, 113454–113474. https://doi.org/10.1109/ACCESS.2021.3104150

Díaz-García, A., González-Robles, A., Fernández-Álvarez, J., García-Palacios, A., Baños, R. M., & Botella, C. (2017). Efficacy of a Transdiagnostic internet-based treatment for emotional disorders with a specific component to address positive affect: Study protocol for a randomized controlled trial. *BMC Psychiatry*, *17*(1), 1–14. https://doi.org/10.1186/s12888-017-1297-z.

Jeong, J., Cho, Y., Shin, Y. S., Roh, H., & Kim, A. (2019). Complex urban dataset with multi-level sensors from highly diverse urban environments. *International Journal of Robotics Research*, *38*(6), 642–657. https://doi.org/10.1177/0278364919843996.

Jin, X., Li, M., Li, D., Ji, J., Pang, J., Wang, J., & Peng, L. (2018). *Development of automatic conveying system for vegetable seedlings*.

Kelechi, A. H., Alsharif, M. H., Agbaetuo, C., Ubadike, O., Aligbe, A., Uthansakul, P., Kannadasan, R., & Aly, A. A. (2021). Design of a low-cost air quality monitoring system using arduino and thingspeak. *Computers, Materials and Continua*, *70*(1), 151–169. https://doi.org/10.32604/cmc.2022.019431.

Khanna, P. R., Howells, G., & Lazaridis, P. I. (2021). Design and Implementation of Low - Cost Real - Time Energy Logger for Industrial and Home Applications. *Wireless Personal Communications*, *119*(3), 2657–2674. https://doi.org/10.1007/s11277-021-08350-1.

Kumar, S., Kolekar, T., Patil, S., Bongale, A., & Kotecha, K. (2022). *A Low-Cost Multi-Sensor Data Acquisition System for Fault*. 1–33.

Leeuw, T., & Boss, E. (2018). *The HydroColor App : Above Water Measurements of Remote Sensing Reflectance and Turbidity Using a Smartphone Camera*. https://doi.org/10.3390/s18010256.

Management, S., Hybrid, U., & Systems, R. E. (2020). *Ukraine Energy Sector Management Using Hybrid Renewable Energy Systems 4, *.*

Moeys, D. P., Member, S., Corradi, F., Li, C., Bamford, S. A., Longinotti, L., Voigt, F. F., Berry, S., Taverni, G., Helmchen, F., & Delbruck, T. (2018). A Sensitive Dynamic and Active Pixel Vision Sensor for Color or Neural Imaging Applications. *IEEE Transactions on Biomedical Circuits and Systems*, *12*(1), 123–136. https://doi.org/10.1109/TBCAS.2017.2759783.

Murad, M., Bayat, O., & Marhoon, H. M. (2021). *Design and implementation of an intelligent home system with two levels of security based on IoT technology*. *21*(1), 546–557. https://doi.org/10.11591/ijeecs.v21.i1.

Pan, C. H., & Pan, H. (2019). *Construction of Wireless Piezoelectric Micro Robots with Arduino Control Module*. 10–17. https://doi.org/10.11159/icmie19.116.

Pham, P. H., Dao, D. V., Amaya, S., Kitada, R., Li, Y., & Sugiyama, S. (2006). Design and fabrication of polymer electrostatic comb-drive actuators for micro conveyer systems. *IEEJ Transactions on Sensors and Micromachines*, *126*(7), 306–311. https://doi.org/10.1541/ieejsmas.126.306.

Ramos-cosi, S., & Vargas-cuentas, N. I. (2021). *Prototype of a System for Quail Farming with Arduino Nano Platform , DHT11 and LM35 Sensors , in Arequipa , Peru*. *11*(11). https://doi.org/10.46338/ijetae1121.

Salam, F. S., Theodosiou, L., Gillibrand, V., & Sharma, K. (2011). A retrospective audit of referrals of 16-17 year olds with reference to substance abuse. *Psychiatria Danubina*, *23* (SUPPL. 1), 194–197.

Selvan, T. A., Viswanathan, A., Madhankumar, S., & Sneha, S. (2019). *Design and Fabrication of Automatic Spring Type Chip Conveyor*. *2*, 917–920. https://doi.org/10.35940/ijrte.B1715.078219.

Selvaraj, A. S., & Anusha, S. (2021). RFID enabled intelligent data analysis in a smart warehouse monitoring system using iot. *Journal of Physics: Conference Series*, *1717*(1). https://doi.org/10.1088/1742-6596/1717/1/012022.

Sun, D., & Böhringer, K. F. (2020). An active self-cleaning surface system for photovoltaic modules using anisotropic ratchet conveyors and mechanical vibration. *Microsystems & Nanoengineering*. https://doi.org/10.1038/s41378-020-00197-z.

Tahir, M. S. M., Hanif, N. H. H. M., & Wahid, A. N. (2022). Maximizing Output Voltage of a Piezoelectric Energy Harvester Via Beam Deflection Method for Low-Frequency Inputs. *IIUM Engineering Journal*, *23*(1), 434–446. https://doi.org/10.31436/IIUMEJ.V23I1.2156.

Taques, F. H., López, M. G., Basso, L. F., & Areal, N. (2021). Indicators used to measure service innovation and manufacturing innovation. *Journal of Innovation and Knowledge*, *6*(1), 11–26. https://doi.org/10.1016/j.jik.2019.12.001.

Yaseen, A., Yahya, H., & Salim, G. (2021). *Investigate the Thermal Behavior of the Portable Weather Monitoring System Based on Arduino Nano*. *11*(2), 495–500.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 178–189

ISSN: 1697-4840, www.jmr.unican.es

The Blended Learning System of a Maritime Training Center

Emerico B. Gepilano[1], Derek Mar O. Montallana[2,*]

ARTICLE INFO

Article history:
Received 12 Aug 2023;
in revised from 24 Aug 2023;
accepted 18 Sep 2023.

Keywords:
Blended learning, Training and Assessment, Maritime Education and Training, Safety Related Competencies.

ABSTRACT

The study assessed the blended learning system of Cebu Reliable and Excellent Seafarers Training (CREST) Center in Cebu City, Philippines in teaching their Basic Training (BT) Course. Specifically, the studylooked in the respondents' extent of course experience in the online learning session of their BT course and level of competence. The findings served as basis of the proposed action plan. This study utilized the descriptive-correlational research design with the use of an adapted modified questionnaire. The study was conducted at Cebu Reliable and Excellent Seafarers Training and Assessment Center, Inc. (CREST), Cebu City. The respondents of the study were all the 50 trainees who enrolled in the BT course of CREST.

This study utilized two adapted modified questionnaire to gather data from the respondents. These questionnaires were subjected to validation and pilot testing. The questionnaire for the trainees' course experience in the online learning session of the blended learning system got Cronbach's alpha coefficient of 0.8494. Meanwhile, questionnaire to gather data on perceived self- efficacy of the maritime trainees' competencies in the four areas of BT course got Cronbach's alpha coefficient of is 0.8446. Both reliability coefficient are above the acceptable minimum reliability coefficient of 0.7000.

Before the actual data gathering, the researcher sent a letter to the operations manager asking permission to conduct the study. Upon receiving permission, the researcher conducted a pilot testing and followed by the actual data gathering. Appropriate statistical tools were used to summarize, analyze and interpret the data from the respondents. Based on the findings of the study, the researched concluded that the blended approach to train seafarers for BT course could be an innovative and effective approach of learning, especially for the younger, tech-savvy generation. The findings also show evidence of the importance of developing the generic skills and adopting new technologies in the maritime training as both show association to various safety-related competencies. In general, the COVID-19 pandemic presents an opportunity for MET institutions to be innovative in their practices, especially in the adoption of blended learning.

1. Introduction.

Maritime Education and Training (MET) is a relatively modern academic program that is continually and thoroughly assessed to ensure quality execution. Moreover, further studies and ingenious experiences have allowed the opportunity to various modalities, improved comprehension of MET factors, and proper practices to be conducted in the maritime cluster (Basak, 2017). MET has consistently centered on the procurement and utilization of hands-on proficiency. This style of learning goes in contrast to typical scholastic instruction which has been believed to substantially emphasize the development of systematic and basic reasoning abilities, cognitive thinking that are less dependent on practical-related tasks (Manuel, 2017). By and large, MET assumes an imperative function in the maritime sector.

In the Philippines, the maritime industry plays a vital role in promoting globalization and providing socio-economic security. In a report from the United Nations Economic and So-

[1]CREST Maritime Training and Assessment Center. Cebu City, Philippines.
[2]CREST Maritime Training and Assessment Center. Cebu City, Philippines.
[*]Corresponding author: Derek Mar O. Montallana. E-mail Address: derekmarmontallana@gmail.com.

cial Commission for Asia and the Pacific (2012), overseas shipping companies in the Philippines made contributions reaching about 60 million pesos for 4.5 % retaining duty to BIR and P 8.2 million in expenses to the Maritime Industry Authority (MARINA). Furthermore, one study laid importance of the 17 Sustainable Development Goals (SDGs) with regards to the maritime business (Wang et al., 2020), as the various jobs played by the business concerning sustainable objectives are introduced, prompting a transition of social or feasible enterprise. As modern shipping is developing into sophistication, there is a need to fill the gap in the Maritime Education and Training to keep pace with the advanced standards in different countries. According to Russel (2017), seafarers on-board should in any case be fit for diagnosing deficiencies and adhere accordingly to worldwide norms of competence.

The need for continuous training (i.e. recertification) has become a central point of controversy for the development of expert individuals in a competing global market (Boulougouris, 2019). Unfortunately, with the outbreak of the Covid-19 pandemic in the country, travel restrictions and uncompromising health protocols has made it excessively challenging to hold consistent face-to-face training and assessment. Thus, the use of blended learning was proposed as an alternative to physical classroom discussions.

Blended learning is portrayed as a wide range of learning that incorporates some part of modular and web-based approaches (Hrastinski, 2019). Generally, blended learning on maritime training institutions (MTIs) typically consists of a synchronous activity for theoretical part of the training (e.g., video-calls) and face to face for the practical exercise part of the training.

The use of blended learning can be a helpful tool for seafarers who aim to work abroad for their families despite the ongoing pandemic. Although, it is to be noted that the application of blended learning onto Maritime Training Institutions (MTIs) has only been done in the Philippines quite recently and no literature has been able to present how such approach has affected the maritime cluster, particularly how it affects the competency level of the Filipino seafarer trainees. As founder and chairman of Cebu Reliable and Excellent Seafarers Training (CREST) and Assessment Center, the researcher believes that it essential conduct this study to come with an action plan for the continuous improvement of the school's services. Furthermore, there is insufficient data to evaluate the cultural and economic factors of such approach that may affect the learning curve of seafarers in the Philippine setting.

2. Methodology.

This study adapted with modification the Student Course Experience Questionnaire (Ginns et al., 2007) to gather the quality of trainees' course experience in the online learning session of the blended learning system implemented by CREST for its BT course. The scale intends to measure the level of learner's experience in regards to the teaching approach as well as their learning environment. The questionnaire covers the following: good teaching scale, clear goals and standards scale, appropriate assessment scale, appropriate workload scale, and generic skills scale. The scale's role in quality assurance would benefit teachers and course developers in regards to adapting better approaches for blended learning.

3. Results.

This section presents the extent of the course experience of the respondents in their online learning session in Basic Training (BT) course.

Table 1: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course in Terms of Good Teaching Scale.

Indicators	Mean	Interpretation
1. The teacher normally gives me helpful feedback on how I am going	3.80	Always
2. The teacher of this degree course motivates me to do my best work.	3.76	Always
3. The teacher makes a real effort to understand difficulties I may be having with my work.	3.70	Always
4. The teacher is extremely good at explaining things.	3.78	Always
5. The teacher works hard to make their subjects interesting.	3.76	Always
6. The teacher puts a lot of time into commenting on my work.	3.62	Always
Overall Mean:	**3.74**	**Always**

Source: Authors.

As indicated in Table above, the aspect of good teaching scale got an overall mean of 3.74 and described as always. Likewise, all the indicators under this aspect are all described as *always*. This implies that teachers teaching online learning sessions in the Basic Training course of CREST continue to provide a diversity of mechanisms of engagement and quality education to their trainees amid Covid-19 pandemic. Accordingly, they highlight in providing feedback to their students, which is a highly valuable approach to enhance learning and promote teacher-student support and interaction despite the distance. They also design activities to help learners understand their topics, which explain the high motivation and interest of trainees, as indicated in the results of the study.

Overall, the findings of the study show that online teaching for the basic training course for maritime trainees is possible when teachers continue to deliver quality teaching. Indeed, regardless of the modality of teaching, an effective teacher has the skills, knowledge, and ways of learning in a digital era (Wood & Shirazi, 2020) who provides safe, inclusive, positive classroom environment (Capella et al., 2015; Gildehaus et al., 2019); socio-emotional support (Hadar et al., 2020), active engagement and interaction (Mutalib et al., 2016), among others.

Nonetheless, it is important to note that online education, especially in maritime training, is not the typical modality used in the Philippines. In fact, many Filipinos are still grappling to engage in the seemingly unorthodox approach of teaching and learning, especially those who are technologically disadvantaged and incapable and economically poor (Tanucan et al., 2021; Tanucan & Uytico, 2021). Hence, the training and development of teachers is crucial so that they can respond to the skills needed for online learning.

Table 2: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course in Terms of Clear Goals and Standards Scale.

Indicators	Mean	Interpretation
1. I have usually had a clear idea of where I am going and what is expected of me in this degree course.	3.76	Always
2. It is always easy to know the standard of work expected	3.78	Always
3. The teacher made it clear right from the start what they expected from students.	3.80	Always
4. It has been easy to discover what is expected of me in this degree course.	3.72	Always
Overall Mean:	**3.77**	**Always**

Source: Authors.

As shown in Table above, the aspect of clear goals and standards scale got an overall mean of 3.77 and described as always. Likewise, all four (4) indicators under this aspect were all described as *always*. This finding implies that the online learning sessions in the Basic Training (BT) course of CREST have clear focus and direction in their lessons, helping their students make sense of their online learning activities and devise strategies to achieve the outcomes expected from them. It has been known that having clear course objectives, goals, and expectations is essential for a successful online education. Existing research concur to this idea, as it helps students devise their personal motivation strategies and have a sense of focus (Swan et al., 2012). This ultimately would help them to prevent burnouts (Roper, 2007) and understand the connections between their class activities and the real world (Dean et al., 2012). It is important to note that course learning outcomes and objectives facilitate effective teaching, as course-related materials and learning activities are purposely aligned to help students see the outline of what pertinent concepts and skills they should attain or develop. For teachers, it may aid them in making the necessary improvements to teaching and learning (Black & William, 2018). Maritime education and training is highly skills-oriented, thus learning objectives for maritime training sessions need to have clear goals and objectives that are align to the professional standards set by associated regulatory and certification bodies.

Table 3: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course in Terms of Appropriate Assessment Scale.

Indicators	Mean	Interpretation
1. The assessment is more on the testing of my understanding.	3.74	Always
2. The questions are more on facts.	3.64	Always
3. Understanding and demonstration of skills is the key to do well in this degree course	3.74	Always
Overall Mean:	**3.71**	**Always**

Source: Authors.

Table above shows that the aspect of appropriate assessment scale got an overall mean of 3.71 and described as *always*. Likewise, all three (3) indicators under this aspect are described as always. This finding implies that the online learning of CREST highlights the use of appropriate learning assessments. Learning assessment is an integral part of the learning process for both face-to-face and online set-up. The advancement in Information and Communication Technology (ICT) has facilitated the adoption of technological processes for the education sector to conduct formal and non-formal education (Kumar-Basak et al., 2018) including the adoption of e- learning. Many academic institutions, especially in the tertiary level, have embraced e- learning as it affords many benefits in learning, teaching and assessment activities (Jafarjalali et al., 2018).

While the conduct of learning assessments in the online set-up has been embraced, it is not without its issues (Rajab et al., 2020). These include plagiarism, maintenance of academic integrity, academic dishonesty, among others (Mukhtar et al., 2020; Laitusis, 2020). These issues should be addressed within the organization, as assessment of and for learning should not be under-emphasized in the teaching and learning process. Hence, the discussion of appropriateness of assessment methods must consider the achievement of the intended outcomes of the curriculum (Gachago et al., 2018). Accordingly, in the process of setting appropriate assessment, what the learners need including their safety and well-being must be considered (Dayagbil et al., 2021).

Table 4: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course in Terms of Appropriate Workload Scale.

Indicators	Mean	Interpretation
1. The course is easy and stress free.	3.74	Always
2. The workload is reasonable.	3.66	Always
3. I am generally given enough time to understand the things I have to learn.	3.80	Always
4. The volume of work in this course is manageable.	3.82	Always
Overall Mean:	**3.76**	**Always**

Source: Authors.

On the aspect of appropriate workload scale, Table above indicates that the overall mean is 3.76 and described as *always*. Likewise, all four (4) indicators under this aspect are all described as *always*. This finding implies that the online learning of CREST sets a reasonable amount of work-load that is manageable and feasible. It is balanced in a way that trainees are learning while having a reasonable amount of challenge. This provides an idea that training or education institutions have to consider customization of learning process as per student's needs, as online learning could be new to most of them.

It is important to note that students are stressed out about education in this time of the pandemic (Shobhit, 2020). More specifically, the physical and mental stress due to online learning (Lathabhavan & Griffiths, 2020; Sahu, 2020; Son et al., 2020) has been the problem that most educators are dealing with in their classes. The cause of this stress is often attributed to the overboard amount of workload (Corrales et al., 2020), and this creates imbalance to students that obstructs learning process (Dhawan, 2020). As the workload of students is not a one-dimensional phenomenon, rather there are many other aspects that come into play such as the mental, physical, and temporal demands as well as the constraints in the use of technology and issues of internet or power connectivity (Sharma, 2020). It is important that education and training institutions make sure that the right amount of academic workload is considered. Suggestions like limiting the academic requirements

and more flexibility provisions could be done (Dayagbil et al., 2021).

Table 5: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course In Terms of Generic Skills Scale.

Indicators	Mean	Interpretation
1. The degree course has helped me develop my ability to work as a team member.	3.80	Always
2. The degree course has sharpened my analytic skills.	3.72	Always
3. As a result of my degree course, I feel confident about tackling unfamiliar problems	3.84	Always
4. The degree course has developed my problem-solving skills.	3.74	Always
5. The degree course has improved my skills in written communication.	3.80	Always
6. My degree course has helped me to develop the ability to plan my own work.	3.76	Always
Overall Mean:	**3.78**	**Always**

Source: Authors.

On the aspect of generic skills scale, Table above shows that the overall mean is 3.78 and described as *always*. Likewise, the six (6) indicators under this aspect are all described as *always*. The finding implies that the online learning of CREST ensures that its trainees develop the generic skills necessary to comprehend and analyze work situations to succeed in their career. The finding also suggests that trainees were given opportunities for practical application, rather than simply talking about or demonstrating what to do, as the development of the generic skills is believed to happen through various practical and engagement classroom activities (Hadiyanto & Ibrahim, 2013). To survive in the maritime industry, one has to learn specific knowledge and skills in the field as well as the different generic skills in order to cope with the demands set in work. In CHED Memorandum Order No. 14, series of 2013, the generic skills sets was emphasized as one of the abilities and skills that a graduate of a maritime-related degree should possess. The skill includes maritime communication and discourses which can be applicable in many other contexts. This is the reason why academes provide opportunities for their students to develop generic skills that can be transferred to other contexts (Badcock et al., 2010; Klegeris et al., 2017). Further, there are already new technologies and automation being introduced and used in maritime work, thereby requiring higher order cognitive skills (Green 2012), technological skills (Cicek et al. 2019), and generic skills, among others.

Table 6: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course in Terms of Perceived Ease of Use of Technology.

Indicators	Mean	Interpretation
1. My interaction with the technologies used in the lesson are clear and understandable.	3.78	Always
2. I find it easy to use the technologies integrated in the lesson.	3.76	Always
3. Interacting with the technologies integrated in the lesson do not require a lot of my mental effort.	3.70	Always
Overall Mean:	**3.75**	**Always**

Source: Authors.

On the aspect of perceived ease of use of technology, Table 6 shows that the overall mean is 3.75 and described as *always*. Likewise, all three (3) indicators are described as *always*. The findings imply that the trainees of CREST have favorable acceptance in the adoption of online learning for their training in BT course. The reason could be attributed to the profile of the respondents because all of them are generation Z learners who are tech-savvy. In other words, the blended learning set-up of CREST for BT training course is an approach that best fits to their interests and capabilities. Hence, explains the positive results with regards to the perceived ease of use of technology. The TAM explained that the perceived ease of use and perceived usefulness serve as the determinants to the intention to use or adopt a technological innovation (Davis, 1989). More so, with the positive relationship between perceived ease of use and perceived usefulness (Anuar & Othman, 2012), it can be inferred that a technology that is easy and useful to the users is necessary for positive adoption and use. Accordingly, this increases the user's efficiency (Gumussoy & Calisir, 2009).

Covid-19 has forced numerous academic institutions to modify their systems and adopt new technologies to continue education. With the unpredictable and rapid spread of the virus, online education system was adopted within a short period of time and it is now an important key mode of instruction for educators (Han & Sa, 2021). Toquero (2020) noted that there is a need to improve the curricula of institutions with great consideration in the use of new teaching methods and technologies. For maritime education and training, the use of innovative strategies in education is warranted to keep pace with the increasing demands of maritime industry.

Table 7: Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course in Terms of Perceived Usefulness of Technology.

Indicators	Mean	Interpretation
1. The different technologies used in the course improves my performance in my studies.	3.92	Always
2. Using the different technologies in my studies increases my productivity.	3.84	Always
3. I find the technologies used in the course to be useful in my studies	3.86	Always
Overall Mean:	**3.87**	**Always**

Source: Authors.

On the aspect of perceived usefulness of technology, Table above shows that the overall mean is 3.87 and described as *always*. Likewise, all three (3) indicators are described as *always*. The findings suggest that the CREST trainees found the tools to be beneficial for learning the Basic Training (BT) course in an online learning setting. It is critical to keep in mind that effective technology adoption requires an understanding of how the technologies and tools to be used will improve performance (Azman et al., 2020). Nevertheless, there will undoubtedly be a drop in employee performance when companies, especially those that use technology- integrated approaches, fail to appropriately convey or demonstrate how the selected technology boosts effectiveness and efficiency in accordance with their work tasks (Abbas et al., 2021).In this regard, organizations that use online learning systems must evaluate critically the technologies they are utilizing in order for the end users to find them advantageous or useful.

Table 8: Summary Table of the Extent of Course Experience in the Online Learning Session in Basic Training (BT) Course.

Aspects of Online Learning	Mean	Interpretation
• Good Teaching Scale	3.74	Always
• Clear Goals and Standards Scale	3.77	Always
• Appropriate Assessment Scale	3.71	Always
• Appropriate Workload Scale	3.76	Always
• Generic Skills Scale	3.78	Always
• Perceived Ease of Use of Technology	3.75	Always
• Perceived Usefulness of Technology	3.87	Always
Aggregate Mean:	**3.77**	**Always**

Source: Authors.

In summary, the extent of course experience of CREST trainees in the online learning session in Basic Training (BT) course is positive, as indicated in the overall mean score of 3.77. Such result is attributed to the well-designed and properly implemented online content, activities, and tools. When the things are considered well before the implementation of online learning, student engagement is enhanced (Zydney et al., 2020). This finding also coheres to the findings of recent studies. For example, Kahn et al. (2017) found that learners become engaged in academic online activities through a process of reflexive deliberation, with students seeking to establish concrete courses of action and sustained practices in the face of uncertainty and complexity. Hence, Well-structured courses and activities aid in increasing student involvement in the learning process as they deal with ambiguous times and shifting learning environments.

3.1. Respondents' Perceived Level of Competence.

This section presents the respondents' perceived level of competence.

Table 9: Respondents' Perceived Level of Competence in Terms of Personal Survival Technique.

Indicators	Mean	Interpretation
1. I am confident to don a life jacket.	3.80	Always
2. I am confident to don and use an immersion suit.	3.70	Always
3. I am confident to safely jump from a height into water.	3.78	Always
4. I am confident to right an inverted life raft while wearing a life jacket.	3.70	Always
5. I am confident to swim while wearing a life jacket.	3.88	Always
6. I am confident to keep a float without a life jacket	3.70	Always
7. I am confident to board a survival craft from ship and water while wearing a life jacket.	3.62	Always
8. I am confident to take initial actions on boarding survival craft to enhance chance of survival.	3.62	Always
9. I am confident to steam a drogue or sea-anchor.	3.70	Always
10. I am confident to operate survival craft equipment.	3.64	Always
11. I am confident to operate location devices, including radio equipment.	3.68	Always
Overall Mean:	**3.71**	**Always**

Source: Authors.

On the aspect of personal survival technique, the overall mean is 3.71 and described as always with all its eleven (11) indicators that got the descriptive score as always. This finding implies that the trainees of CREST have the basic knowledge and skills to survive at sea in the event of ship abandonment. This further suggests that the practical training session of the blended learning of CREST has yielded positive results to the trainees given their scores.

The Personal Survival Techniques (PST) is purposely designed to be part of the mandatory basic safety training in the STCW code so that seafarers acquire self-protection abilities in emergency situations including the survival at sea and deployment of safety equipment. There is no ship which can be operated that is hazard or error-free. As most accidents at the sea are inevitable and they are usually caused by human errors (Gregory & Shanahan, 2012; Lappalainen et al., 2014), training on personal survival is necessary.

Buted (2014) has noted that training activities should equip seafarers with basic competencies, especially in terms of security and safety of passengers and crew. That is why from the donning of a lifejacket to the preparation and operation of survival craft, all of these are essential to the protection and maintenance of the seafarers of their own and others safety at sea. The findings of this study help support that the blended learning approach for the mandatory training of seafarers could be a feasible way for maritime education and training institutions to achieve the mandatory basic safety training stipulated in the STCW code.

Table 10: Respondents' Perceived Level of Competence in Terms of Fire Prevention and Fire Fighting.

Indicators	Mean	Interpretation
1. I am confident to use various types of portable fire extinguishers.	3.80	Always
2. I am confident to use self-contained breathing apparatus;	3.71	Always
am confident to extinguish smaller fires, e.g. electrical fires, oil fires and propane fires;	3.69	Always
am confident to extinguish extensive fires with water (jet and spray nozzles);	3.63	Always
am confident to extinguish fires with either foam, powder or any other suitable chemical agent;	3.73	Always
am confident to enter and pass through, with life-line without breathing apparatus, a compartment into which high expansion foam has been injected	3.71	Always
am confident to fight fire in smoke-filled enclosed spaces wearing self-contained breathing apparatus.	3.67	Always
I am confident to extinguish fire with water fog, or any other suitable fire-fighting agent in an accommodation room or simulated engine-room with fire and heavy smoke.	3.65	Always
am confident to extinguish an oil fire with fog applicator and spray nozzles; dry chemical powder or foam applicators	3.72	Always
I am confident to effect a rescue in a smoke-filled space wearing breathing apparatus.	3.70	Always
Overall Mean:	**3.70**	**Always**

Source: Authors.

On the aspect of fire prevention and fire-fighting, the overall mean is 3.70 and described as *always*. Likewise, all indicators are described as *always*. The finding implies that the trainees of CREST have the basic knowledge and skills necessary to minimize the risk and impacts of fires aboard ship including the causes of fires and means to extinguish them.

Fires and explosions have been assessed by the European Maritime Safety Agency (EMSA) as one of the top five causes of accidents on board ships (Salem, 2019). Fires usually originate in the engine room which can spread to other parts of the ship, halting the ship's operations or even the loss of many lives. Ellis (2011) analyzed the deaths of ships carrying containerized dangerous goods in the years 1998–2008 and found out that ignition of incorrectly declared goods is contributory to the accidents. Uğurlu et al. (2012) examined 18 fire & explosion accident investigation reports of oil tankers in the years 1998-2010 and concluded that the accidents were caused by inappropriate equipment use, hot working, combustible gas accumulation and cargo leakage. You and Chung (2015) analyzed cases of ship fires and explosions in the years 2009-2013 and concluded that

lack of safety awareness was the common reason. Rothblum (2020) also found out that human error contributes to 75% of fires & explosions.

Given the occurrence of the many fire-and explosion-related accidents in on board ships, it is important that seafarers are continuously trained and assessed to prevent fires or minimize its impact more efficiently and effectively. The results of this study would help shed light on the feasibility of Blended Learning (BL) as an innovation for seafarer's training.

Table 11: Respondents' Perceived Level of Competence in Terms of Elementary First Aid.

Indicators	Mean	Interpretation
1. I am confident to position casualty.	3.68	Always
2. I am confident to apply resuscitation techniques.	3.60	Always
3. I am confident that I can control bleeding.	3.66	Always
4. I am confident to apply appropriate measures of basic shock management.	3.62	Always
5. I am confident to apply appropriate measures in events of burns and scalds, including accidents caused by electric current.	3.68	Always
6. I am confident to rescue and transport a casualty.	3.62	Always
7. I am confident to improvise bandages and use materials in the emergency kit.	3.72	Always
Overall Mean:	**3.65**	**Always**

Source: Authors.

On the aspect of elementary first aid, the overall mean rating is 3.65 and described as *always*. Likewise, all of the seven (7) indicators are described as *always*. The findings implies that the trainees of CREST have the basic knowledge and skills necessary to take on immediate action for most common emergencies aboard ship. These include the ability to check for vital signs, bleeding, and other forms of injuries. The finding further suggests the feasibility of Blended Learning (BL) in developing the competence of elementary first aid.

Seafaring is a high risk-occupation given that its nature usually takes place in the isolated environment (Oldenburg et al., 2010). More so, accidents are inevitable and the predominant medical emergencies were trauma (Dahl, 2005; McKay, 2007), which usually are caused by the ship's movements and the dangerous nature of the working environment, especially on container and general cargo ships (Oldenburg et al., 2010). Further, seafarers often feel overwhelmed due to low personnel and their lack of experience with large-scale rescue operations on the high seas (Dittmann et al., 2015). This sometimes could lead to injuries and sickness, which calls for seafarers to perform first aid treatment themselves.

The telemedical reports also noted that medical emergencies related to surgical , internal, and urological health disorders were the frequently observed (Flesche & Jalowy, 2007; Grappasonni et al., 2012) While having a medical doctor on passenger and larger research ships is mandatory, on merchant vessels the emergency interventions is carried out by nautical officers. Thus, the reason why all seafarers have to receive first aid training as part of their studies at maritime education and training schools or institutes. As to the question on the feasibility of Blended Learning (BL) as a form of training approach for first aid, the findings of this study help shed light on this matter.

Table 12: Respondents' Perceived Level of Competence in Terms of Personal Safety and Social Responsibility.

Indicators	Mean	Interpretation
1. I am confident that I have the ability to comply with emergency procedures.	3.76	Always
2. I am confident that I have the ability to take precautions to prevent pollution of the marine environment.	3.74	Always
3. I am confident that I have the ability to observe safe working practices.	3.76	Always
4. I am confident that I have the ability to contribute effective communications on board ship.	3.68	Always
5. I am confident that I have the ability to contribute effective human relationships on board ship.	3.78	Always
6. I am confident that I understand and can take necessary actions to control fatigue.	3.70	Always
Overall Mean:	**3.74**	**Always**

Source: Authors.

On the aspect of personal safety and social responsibility, the overall mean rating is 3.74 and described as *always*. Likewise, all the indicators under this aspect are described as *always*. This finding implies that the trainees of CREST have the knowledge and skills to comply with various emergency and safety procedures, accident prevention, clear and effective communication, and harmonious working relationships. The finding further suggests the feasibility of Blended Learning (BL) in developing the competence on personal safety and social responsibility.

In the maritime industry, apart from the efficient maritime transport and navigational system, the safetyof the crew and environment, are among the top line priorities (Javier & Aguado, 2012). This is because the continuous expansion of the industry has not onlyled to the growth of the number of vessels, but also the potential risks and hazards (Baalisampang et al., 2018). More so, apart from the idea that working on board ships has a higher fatal accident rate than other industries like the construction industry (Roberts et al., 2014), manymaritime accidents are directly or indirectly attributed to the unsafe acts and/or errors of crews (Heij & Knapp, 2018) To ensure safe and successful operation of ships, seafarers need to have qualification and competence. The different on board training are also essential to prepare them to continuously develop their knowledge and skills. Various studies have been conducted regarding the improvement of maritime training. Aside from making sure that the training curriculum is realistic, training conditions should be improved in a way that targets the satisfaction of the seafarers (Sin & Im, 2015).

Table 13: Respondents' Perceived Level of Competence.

Indicators	Mean	Interpretation
• Personal Survival Technique	3.71	Always
• Fire Prevention and Fire Fighting	3.70	Always
• Elementary First Aid	3.65	Always
• Personal Safety and Social Responsibility	3.74	Always
Aggregate Mean:	**3.70**	**Always**

Source: Authors.

For this reason, the maritime industry is making sure that high-quality innovative programs for training are in place. One of these is the use of online learning. While the use of online learning has become a norm for many maritime companies, this learning set-up is still new in the Philippines. Hence, questions

about the feasibility of online learning for maritime training are still being tabled. This study helps answer this gap.

In summary, the CREST trainees perceived level of competence in Basic Training (BT) course competencies is positive, as indicated in the overall mean score of 3.70. Such a result suggests that CREST's blended learning approach is effective in assisting its students in meeting the outcomes expected of them. The goal of the Basic Training (BT) course is to give seafarers the knowledge and skills in doing the responsibilities related to the handling, usage, and emergency response. This comprises four short courses, namely personal survival techniques, fire prevention and fire-fighting, elementary first aid and personnel safety and social responsibilities. The teaching-learning process is still being tested by the pandemic, thus institutions need to find new ways to reinvent their methods in order to keep teaching and learning going and ensure that students are continually receiving high-quality instruction.

3.2. Relationship of the Extent of Course Experience and Level of Competencies.

This section presents the test of the significance of the relationship between the extent of the course experience in the Basic Training (BT) course and the level of competencies of the respondents. Tables below summarized the results.

As shown in table 14, there are pairs of variables that the test of the relationship cannot be performed considering that all responses are the same. Hence, cross tabulation, a requirement in doing Chi-square test of association, is impossible. Furthermore, there are pairs of variables which yield not significant results. It means that those paired variables have no significant relationship of effect to one another. Moreover, there are pairs of variables which yield significant results. It means that the paired variables have a significant effect on one another. However, these significant effects between the paired variables vary according to the strength based on the computed Pearson's coefficient C.

As indicated in table above, generic skills scale and fire prevention and fire- fighting has moderate significant relationship (15.986>3.841, C=0.49, moderate), while two (2)pairs of variables have yield slight significant relationship – generic skills scale and elementary first aid (4.228 > 3.841, C = 0.28, slight) and generic skills scale and personal safety and social responsibility (4.228 > 3.841, C = 0.28, slight). This finding demonstrates the importance of generic skills in maritime industry, especially in the accomplishment of the safety and hazard- prevention competencies in the Basic Training (BT) course such as the prevention and fire- fighting, elementary first aid, personal safety and social responsibility. This finding supports the contention regarding the importance of generic skill sets in the modern workplace and in preparation for entry to the labor market (Mclean et al., 2013).

Accordingly, with the maritime industry that is extremely high-risk (Hetherington et al., 2006) due to the vulnerability of being exposed to noxious substances, minor and major injuries, extreme weather events, fire, and explosions, among others (Håvold, 2010), having well- developed general skill set can help navigate with life circumstances (Arum & Roksa, 2011; Hyytinen et al., 2019).

On the other hand, as gleaned in Table 3, there is a slight relationship observed in the two (2) variables related to technology such as the perceived usefulness of technology and elementary first aid (4.228 > 3.841, C = 0.28, slight), and perceived usefulness of technology and personal safety and social responsibility > 3.841, C = 0.028, slight). This finding demonstrates the link of technological skills and maritime safety skills; albeit slightly. It is important to note that the successful accomplishment of elementary first aid and personal safety and social responsibility necessitates one to have the knowledge and skills in the use of technology. For instance, the use of accelerometer (ACC), Spo2, and ECG sensors are the technologies used to monitor vital signs in this modern time. Being aware of the different technological demands in the workplace is a component in the achievement of personal safety and social responsibility onboard ships. With the tenets of industry 4.0, it is increasingly important to integrate new technology with traditional technology, equipment, and management to realize not only industrial transformation and upgrading (Lee et al., 2017), but also work safety (Lyu et al., 2022). There is a recognized need worldwide for on board training in maritime safety. Engaging the trainees with the current and latest technology would help ensure that they can operate within the basic technical environment of the ship and they can help in terms of the technical requirement needed to successfully conduct safety measures and provide immediate medical care to patients in an emergency situation.

Conclusions

The blended approach to train seafarers for Basic Training (BT) course could be an innovative and effective approach of learning, especially for the younger, tech- savvy generation. The findings also show evidence of the importance of developing the generic skills and adopting new technologies in the maritime training as both show association to various safety-related competencies. In general, the COVID-19 pandemic presents an opportunity for MET institutions to be innovative in their practices, especially in the adoption of blended learning.

Recommendations.

Based on the findings of the study, the following are recommended:

1. Future researchers may conduct studies on the following:
   (a) Experimental studies to prove the effectiveness of blended learning in the development of the competencies in Basic Training (BT) course and other mandatory courses stipulated in STCW manual;
   (b) Correlational studies that will take into account more possible related factors (e.g. age, sex, socio-economic status) in the success of the implementation of Blended Learning (BL);

Table 14: Relationship Between the Extent of Course Experience and Level of Competencies in Basic Training Course.

Variables	Df	Chi-square	Critical Value	Decision on Ho	Interpretation
Good Teaching Scale in relation to:					
• Personal Survival Technique • Fire Prevention and Fire Fighting • Elementary First Aid • Personal Safety and Social Responsibility	(test cannot be performed; all responses are the same)				
Clear Goals and Standards Scale in relation to:					
• Personal Survival Technique • Fire Prevention and Fire Fighting • Elementary First Aid • Personal Safety and Social Responsibility	(test cannot be performed; all responses are the same)				
Appropriate Assessment Scale in relation to:					
• Personal Survival Technique	(test cannot be performed; all responses are the same)				
• Fire Prevention and Fire Fighting	2	0.113	5.991	Failed to Reject Ho	Not Significant
• Elementary First Aid	2	2.817	5.991	Failed to Reject Ho	Not Significant
• Personal Safety and Social Responsibility	2	2.871	5.991	Failed to Reject Ho	Not Significant
Appropriate Workload Scale in relation to:					
• Personal Survival Technique	(test cannot be performed; all responses are the same)				
• Fire Prevention and Fire Fighting	1	0.021	3.841	Failed to Reject Ho	Not Significant
• Elementary First Aid	1	0.65	3.841	Failed to Reject Ho	Not Significant
• Personal Safety and Social Responsibility	1	0.065	3.841	Failed to Reject Ho	Not Significant
Generic Skills Scale in relation to:					
• Personal Survival Technique	(test cannot be performed; all responses are the same)				
• Fire Prevention and Fire Fighting	1	15.986	3.841	Reject Ho	Significant C=0.49, moderate
• Elementary First Aid	1	4.228	3.841	Reject Ho	Significant C=0.28, slight
• Personal Safety and Social Responsibility	1	4.228	3.841	Reject Ho	Significant C=0.28, slight
Perceived Ease of Use of Technology in relation to:					
• Personal Survival Technique	(test cannot be performed; all responses are the same)				
• Fire Prevention and Fire Fighting	1	0.065	3.841	Failed to Reject Ho	Not Significant
• Elementary First Aid	1	0.204	3.841	Failed to Reject Ho	Not Significant
• Personal Safety and Social Responsibility	1	0.204	3.841	Failed to Reject Ho	Not Significant
Perceived Usefulness of Technology in relation to:					
• Personal Survival Technique	(test cannot be performed; all responses are the same)				
• Fire Prevention and Fire Fighting	1	0.065	3.841	Failed to Reject Ho	Not Significant
• Elementary First Aid	1	4.228	3.841	Reject Ho	Significant C=0.28, slight
• Personal Safety and Social Responsibility	1	4.228	3.841	Reject Ho	Significant C=0.28, slight

Source: Authors.

(c) Qualitative studies that will provide an in-depth exploration of experience and perception in the use of blended learning for maritime-related training.

2. Implement the proposed action plan.

Proposed Action Plan.

Instead of reverting back to how maritime training was developed and conducted in the past, the pandemic has introduced the use of Blended Learning (BL), a new system that favorably accepts the employment of diverse teaching approaches with a strong emphasis on technological integration. With training institutions all over the world redesigning its practices to spur innovation and improve clientele satisfaction and engagement, blended learning is becoming a new normal. The Cebu Reliable and Excellent Seafarers Training (CREST) Center intends to demonstrate through the action plan for an enhanced blended learning system, a renewal of its commitment to improve its training practices and protocols in order to provide responsive and up-to-date international training standards for professional mariners.

Objectives:

- To equip physical classrooms and other learning environments with the necessary infrastructure to support blended learning;
- To provide continuing professional learning support to staff on blended learning;
- To establish Information Technology Services (ITS) for staff and trainees to assist them with their technology-related concerns; and
- Reward best practice blended learning programs utilized at CREST.

References.

Books.

Arum, R., & Roksa, J. 2011. *Academically adrift: Limited learning on college campuses*. Chicago: University of Chicago Press.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: W.H. Freeman & Co.

Dean, C. B., Stone, B., Hubbell, E. & Pitler, H. (2012). *Classroom instruction that works: Research-based strategies for increasing student achievement* (2nd ed.). Alexandria, VA: ASCD.

Dewey, J. (1959). *My pedagogic creed*. New York: Teachers College, Columbia University.

Garrison, D. R. (2017). *E-learning in the 21st century: A framework for research and practice* (3rd ed.). New York: Routledge.

Garrison, D. R. & Vaughan, N. (2008). *Blended learning in higher education*. San Francisco: Jossey-Bass.

Gregory, D. & Shanahan, P. (2012). *The human element: A guide to human behaviour in the shipping industry*. United Kingdom: Witherby.

Russell, P. (2017). *Maritime Education and Training (MET)*. Encyclopedia of Maritime and Offshore Engineering, 1-11.

Singh, H. (2003). *Building effective blended learning programs*. Educational Technology-Saddle Brook Then Englewood Cliffs NJ-, 43(6), 51-54.

Journals, Periodicals and Handbooks.

Abbas, A., Ekowati, D. & Suhariadi, F. (2021). Managing individuals and organizations through leadership: Diversity consciousness roadmap. In *Handbook of Research on Applied Social Psychology in Multiculturalism*, pp. 47-71. IGI Global.

Anuar, S. & Othman, R. (2012). Determinants of online tax payment system in Malaysia. *International Journal of Public Information Systems, 1*, 17–32.

Arbaugh, J. B. (2007). An empirical verification of the community of inquiry framework. *Journal of Asynchronous Learning Networks, 11*(1), 73-86.

Azman, B. B., Okafor, D. J. & Nico, M. (2020). The influence of perceived ease of use and perceived usefulness on the intention to use a suggested online advertising workflow. *Canadian International Journal of Science and Technology, 6*(14), 162-174.

Badcock, P. B., Pattison, P. E. & Harris, K. L. (2010). Developing generic skills through university study: A study of arts, science and engineering in Australia. *Higher Education, 60*, 441–458.

Baalisampang, T., Abbassi, R., Garaniya, V., Kahn, F. & Dadashzadeh, M. (2018). Review and analysis of fire and explosion accidents in maritime transportation. *Ocean Engineering, 158*, 350-366.

Basak, S. K. (2017). A framework on the factors affecting to implement maritime education and training system in educational institutions: A review of the literature. *Procedia Engineering, 194*, 345 - 350.

Băutu, E., Atodiresei, A. N. & Băutu, A. (2018). Design of self-paced blended- learning computer programming courses for maritime students. Scientific Bulletin "Mirceacel Batran". *Naval Academy, 21*(1), 1-7.

Black, P. & Wiliam, D. (2018). Classroom assessment and pedagogy. *Assessment in Education: Principles, Policy & Practice, 25*(6), 551-575.

Boulougouris, E., Mizythras, P., Chrysinas, L., Vavourakis, G., Theotokatos, G., Aymelek, M. & Kurt, I. (2019). Developing multidisciplinary blended learning courses for maritime education with cross-European collaboration. *WMU Journal of Maritime Affairs, 18*(2), 319-340.

Buted, D. R. (2014). Effectiveness of basic safety training among cruise line students. *Asia Pacific Journal of Multidisciplinary Research, 2*(3). 161-169.

Cappella, E., Aber, J. L. & Kim, H. K. (2015). Teaching beyond achievement tests: Perspectives from developmental and education science. In D. H. Gitomer, &

C. A. Bell (Eds.), *Handbook of Research on Teaching* (pp. 249-348). Washington, DC: American Education Research Association.

Chen, X., Bai, X. & Xiao, Y. (2017). The application of E-learning in maritime education and training in China. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 11*(2).

Chen, Y., Lei, J. & Cheng, J. (2019). What if online students take on the responsibility: Students' cognitive presence and peer facilitation techniques? *Online Learning, 23*(1), 37-61.

Cicek K., Akyuz E. & Celik M (2019). Future skills requirements analysis in maritime industry. *Procedia Computer Science, 158*, 270–274.

Corrales, C., Rojas, J. & Atoche, W. (2020). Impact of Pre-professional Practices on the Excessive Mental Workload of University Engineering Students. *International Conference on Applied Human Factors and Ergonomics*, 437–444. Cham: Springer.

Dahl, E. (2005). Medical practice during a world cruise: A descriptive epidemiological study of injury and illness among passengers and crew. *International Maritime Health, 56*(1–4), 115-128.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Dayagbil, F. T., Palompon, D. R., Garcia, L. L. & Olvido, M. M. J. (2021). Teaching and learning continuity amid and beyond the pandemic. *Frontiers in Education, 6*, 678-692.

Dhawan, S. (2020). Online learning: A panacea in the time of Covid-19 crisis. *Journal of Educational Technology Systems, 49*(1), 5–22.

Dittmann, F., Dirksen-Fischer, M., Harth, V., von Munster, T., Mache, S. & Oldenburg, M. (2015). The rescue of refugees: a challenge for the merchant fleet. *International Maritime Health, 66*(4), 252–7.

Ellis, J. (2011). Analysis of accidents and incidents occurring during transport of packaged dangerous goods by sea. *Safety Science, 49*(8), 1231-1237.

Flesche, C. W. & Jalowy, A. (2007). Telemedicine in medical emergency situations in terms of maritime personnel. *Dtsch Med Wochenschr, 132*(9), 463-464.

Gachago, D., Jones, B. & Edwards, S. (2018). Towards flexible learning through distance learning: ND real estate learners' experiences. *ICEL 2018 13th International Conference on E-Learning*. Capetown: Academic Conferences and Publishing Limited, 93.

Garrison, D. R., Anderson, T. & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *Internet Higher Education, 2*, 87–105.

Gildehaus, L., Cotter, P., Buck, S., Sousa, M., Hueffer, K. & Reynolds, A. (2019). The research, advising, and mentoring professional: A unique approach to supporting underrepresented students in biomedical research. *Innovative Higher Education, 44*, 119–131.

Ginns, P., Prosser, M. & Barrie, S. (2007). Students' perceptions of teaching quality in higher education: The perspective of currently enrolled students. *Studies in Higher Education, 32*, 603-615.

Graham, C. R. (2006). *Blended learning systems*. The Handbook of Blended Learning: Global Perspectives Local Designs, 3-21.

Grappasonni, I., Petrelli, F. & Amenta, F. (2012). Deaths on board ships assisted by the Centro Internazionale Radio Medico in the last 25 years. *Travel Medicine and Infectious Disease, 10*(4):186–189.

Green, F. (2012). Employee involvement, technology and evolution in job skills: A task-based analysis. *Industrial and Labor Relations Review, 65*(1). 36–67.

Grewal D. & Haugstetter, H. (2007). Capturing and sharing knowledge in supply chains in the maritime transport sector: Critical issues. *Maritime Policy and Management, 34* (2), 169-183.

Gumussoy, C. A. & Calisir, F. (2009). Understanding factors affecting e-reverse auction use: An integrative approach. *Computers in Human Behavior, 25*(4): 975-988.

Hadar, L. L., Ergas, O., Alpert, B. & Ariav, T. (2020). Rethinking teacher education in a vuca world: Student teachers' social-emotional competencies during the Covid-19 crisis. *European Journal of Teacher Education, 43*, 573-586.

Hadi, Y. & Ibrahim, M. S. B. (2013). Students' generic skills at the National University of Malaysia and the National University of Indonesia. *Procedia – Social and Behavioural Sciences*, 83, 71–82.

Haiyan, Y. (2016). Blended learning will be applicable in maritime education and training. *Journal of Shipping and Ocean Engineering, 6*, 31-34.

Han, J. H. & Sa, H. J. (2021). Acceptance of and satisfaction with online educational classes through the technology acceptance model (TAM): The COVID-19 situation in Korea. *Asia Pacific Education Review, 11*, 1–13.

Håvold, J. I. (2010). Culture in maritime safety. *Maritime Policy & Management, 27*(1), 79-88.

Heij, C. & Knapp, S. (2018). Predictive power of inspection outcomes for future shipping accidents: An empirical appraisal with special attention for human factor aspects. *Maritime Policy & Management, 45* (5), 604-621.

Hetherington, C., Flin, R. & Mearns, K. (2006). Safety in shipping: The human element. *Journal of Safety Research, 37*(4), 401-411.

Hilliard, L. P. & Stewart, M. K. (2019). Time well spent: Creating a community of inquiry in blended first-year writing courses. *Internet Higher Education, 41*, 11–24.

Hrastinski,S.(2019).What do we mean by blended earning? *TechTrends, 63*(5), 564- 569.

Hyytinen, H., Toom, A. & Shavelson, R. J. (2019). Enhancing scientific thinking through the development of critical thinking in higher education. In M. Murtonen & K. Balloo (Eds.), *Redefining Scientific Thinking for Higher Education: Higher-Order Thinking, Evidence-Based Reasoning and Research Skills* (pp. 59-78).

Jafarjalali, S. M., Mahdizadeh, E., Mahmoudi, M. R. & Moro, S. (2018). Analytical assessment process of e-learning

domain research between 1980 and 2014. *International Journal of Management in Education, 12*(1). 43–56.

Javier, F. V. & Aguado, C. (2012). The vessel traffic management system at the Batangas baseport: Basis of enhancing vessel traffic services at the Batangas bay. *International Journal of Business and Management, 1*(1): 57-78.

Joo, Y. J., Lim, K. Y. & Kim, E. K. (2011). Online university students' satisfaction and persistence: Examining perceived level of presence, usefulness and ease of use as predictors in a structural model. *Computers & Education, 57*(2), 1654-1664.

Kahn, P., Everington, L., Kelm, K., Reid, I. & Watkins, F. (2017). Understanding student engagement in online learning environments: The role of reflexivity. *Educational Technology Research and Development, 65*, 203–218.

Klegeris, A., McKeown, S. B., Hurren, H., Spielman, L. J., Stuart, M. & Bahniwal, M. (2017). Dynamics of undergraduate student generic problem-solving skills captured by a campus-wide study. *Higher Education, 74*, 877–896.

Kumar-Basak, S., Wotto, M. & Belanger, P. (2018). E-learning, M-learning and D- learning: Conceptual definition and comparative analysis. *E-Learning and Digital Media, 15*(4), 191-216.

Lappalainen, J., Kunnaala, V. & Tapaninen, U. (2014). Present pilotage practices in Finland. *WMU Journal of Maritime Affairs*, *13*(1), 77-99.

Lathabhavan, R. & Griffiths, M. (2020). First case of student suicide in India due to the Covid-19 education crisis: A brief report and preventive measures. *Asian Journal of Psychiatry*, *53*(1), 22-40.

Lee, W., Lin, K., Seto, E. & Migliaccioa, G.C. (2017). Wearable sensors for monitoring on-duty and off-duty worker physiological status and activities in construction. *Automation in Construction, 83*, 341-353.

Liu, Y., Li, H. & Carlsson, C. (2010). Factors driving the adoption of m-learning: An empirical study. *Computers & Education, 55* (3), 1211-1219.

Lyu, Q., Fu, G., Wang, Y., Li, J., Han, M., Peng, F. & Yang, C. (2022). How accident causation theory can facilitate smart safety management: An application of the 24Model. *Process Safety and Environmental Protection, 162*, 878-890.

Manuel, M. E. (2017). Vocational and academic approaches to maritime education and training (MET): Trends, challenges and opportunities. *WMU Journal of Maritime Affairs, 16*(3), 473-483.

McLean, M., Murdoch-Eaton, D. & Shaban, S. (2013). Poor English language proficiency hinders generic skills development: A qualitative study of the perspectives of first-year medical students. *Journal of Further and Higher Education, 37*(4), 462–481.

McKay, M. P. (2007). Maritime health emergencies. *Occupational Medicine, 57*(6), 453-455.

Mukhtar, K., Javed, K., Arooj, M. & Sethi, A. (2020). Advantages, limitations and recommendations for online learning during Covid-19 pandemic era: Online learning during Covid-19 pandemic era. *Pakistan Journal of Medical Sciences, 36.* (Covid19-S4).

Nazarenko, A. L. (2015). Blended learning vs traditional learning: What works? (A case study research). *Procedia-Social and Behavioral Sciences, 200*, 77-82.

Oldenburg, M., Baur, X. & Schlaich, C. (2010). Occupational risks and challenges of seafaring. *Journal of Occupational Health, 52*(5), 249–256.

Patwardhan, V., Rao, S. & Prabhu, N. (2020). Community of inquiry (CoI) framework and course design as predictors of satisfaction in emergency remote teaching: Perspectives of hospitality management students. *Journal of E-Learning and Knowledge Society, 16*(4), 94–103.

Pastor, C. K. L. (2020). Sentiment analysis on synchronous online delivery of instruction due to extreme community quarantine in the Philippines caused by Covid-19 pandemic. *Asian J. Multi. Stud. 3*(1), 1–6.

Rajab, M. H., Gazal, A. M. & Alkattan, K. (2020). Challenges to online medical education during the Covid-19 pandemic. *Cureus, 12*(7).

Roberts, S. E., Nielsen, D., Kotłowski, A. & Jaremin, B. (2014). Fatal accidents and injuries among merchant seafarers worldwide. *Occupational Medicine, 64*(4), 259–266.

Roper, A. R. (2007). How students develop online learning skills. *Educause Quarterly, 30* (1), 62.

Rothblum, A. M. (2000, October). Human error and marine safety. In *National Safety Council Congress and Expo, Orlando, FL* (Vol. 7).

Sahu, P. (2020). Closure of universities due to Coronavirus Disease 2019 (Covid- 19): Impact on education and mental health of students and academic staff. *Cur*eus, *12*(4), 4.

Saint-Jacques, A. (2013). Effective teaching practices to foster vibrant communities of inquiry in synchronous online learning. In Z. Akyol & R. Garrison (Eds.), *Educational Communities of Inquiry: Theoretical Framework, Research, and Practice* (pp. 84–108). IGI Global.

Salem, A. (2019). Vehicle-deck fires aboard Ropax ships: A comparison between numerical modelling and experimental results. *Polish Maritime Research, 2*(102), 26, 155–162.

Son, C., Hegde, S., Smith, A., Wang, X. & Sasangohar, F. (2020). Effects of COVID-19 on college students' mental health in the United States: Interview survey study. *Journal of Medical Internet Research, 22*(9).

Siah, C., Lim, F., Lau, S. & Tam, W. (2020) The use of the community of inquiry survey in blended learning pedagogy for a clinical skill-based module. *Journal of Clinical Nursing, 30* (3–4), 454–465.

Sin, H. S. & Im, M. H. (2015). A basic study on the satisfaction of on-board training for cadets in shipping company. *Journal of Fisheries and Marine Sciences Education*, *27*(2), 441-451.

Shea, P., Li, C. S., Swan, K. & Pickett, A. (2005). Developing learning community in online asynchronous college courses: The role of teaching presence. *The Journal of Asynchronous Learning Networks, 9*(4), 59-82.

Sheridan, K., Kelly, M. A. & Bentz, D. T. (2013). A follow-up study of the indicators of teaching presence critical to students in online courses. In Z. Akyol & R. Garrison (Eds.),

Educational Communities of Inquiry: Theoretical Framework, Research, and Practice (pp.67–83). IGI Global.

Swan, K., Mattews, D., Bogle, L., Boles, E. & Day, S. (2012). Linking online course design and implementation to learning outcomes: A design experiment. *The Internet & Higher Education, 15*(2), 81-88.

Szeto, E. (2014). Community of inquiry as an instructional approach: What effects of teaching, social and cognitive presences are there in blended synchronous learning and teaching? *Computers & Education, 81*, 191-201.

Tashabalala, M., Ndeya-Ndereya, C. & Merwe, T. (2014). Implementing blended learning at a developing university: Obstacles in the way. *The Electronic Journal of E-Learning, 12*(1), 101-110.

Tanucan, J. C., Hernani, M. R. & Diano, F. (2021). Filipino physical education teachers' technological pedagogical content knowledge on remote digital teaching. *International Journal of Information and Education Technology, 11*(9), 416–423.

Tanucan, J. C. & Uytico, B. J. (2021). Webinar-based capacity building for teachers: Lifeblood in facing the new normal of education. *Pertanika Journal of Social Sciences & Humanities, 29*(2), 1035-1053.

Toquero, C. M. (2020). Challenges and opportunities for higher education amid the Covid-19 pandemic: The Philippine context. *Pedagogical Research, 5*(4).

Wang, X., Yuen, K. F., Wong, Y. D. & Li, K. X. (2020). How can the maritime industry meet sustainable development goals? An Analysis of sustainability reports from the social entrepreneur ship perspective. *Transportation Research Part D: Transport and Environment, 78*, 102173.

Wood, R. & Shirazi, S. (2020). A systematic review of audience response systems for teaching and learning in higher education: the student experience. *Computers & Education, 153*, 103896.

You, J. & Chung, Y. (2015). Study on the ship fire analysis according to explosion hazard. *Fire Science Engineering, 29*(1), 80-86.

Zydney, J. M., Warner, Z. & Angelone, L. (2020). Learning through experience: Using design based research to redesign protocols for blended synchronous learning environments. *Computers and Education*, *143*.

Online Sources.

Commission on Higher Education (CHED). (2020). *CHED Covid-19 advisory no. 1.* Retrieved February 28, 2022 from https://cutt.ly/YMNftrA.

Department of Education (DepEd) (March 15, 2020). DM No. 042, s. 2020. G*uidelines for the remainder of school year 2019-2020 in light of covid-19 measures*. Retrieved on February 20, 2022 from https://cutt.ly/TMNdrLp.

Department of Information and Communication Technology (DICT) (2017, October 17). *State of the internet report*. Retrieved on March 3, 2022 from https://cutt.ly/NMNfz3a.

Digital Marketing Institute (2018, May 17). *What are the benefits of blended learning?* Retrieved on February 18, 2002 from https://cutt.ly/cMNfIoV.

European Maritime Safety Agency (2018). *Annual overview of marine casualties and incidents 2018.* Lisboa. Retrieved on March 3, 2022 from https://cutt.ly/SMNsQBH.

Hernando-Malipot, M. (2020, July 07). *DepEd sees 20% enrollment drop due to COVID-19*. Manila Bulletin. Retrieved on March 4, 2022 from https://cutt.ly/9MNfVa0.

Laitusis, V. (2020). 3 *Assessment Challenges in a Remote Learning Environment*. Retrieved on March 4, 2022 from https://-cutt.ly/tMNgtcQ.

Lynch, M. (2018, May 18). *5 Major Benefits of Blended Learning. Education Week*. Retrieved March 3, 2022 from https://cutt.ly/6MNggSx.

Mirandilla-Santos M. (2016). P*hilippine broadband: A policy brief. Arangkada Philippines-Policy.4:1–20.* Retrieved on March 4, 2022 from https://cutt.ly/0MNgbDg.

Mutalib, M. A., Halim, N. D. A. & Yahaya, N. (2016). Meta-analysis on interaction in online learning. In *Conference Proceedings. Universiti Teknologi Malaysia*. Retrieved on March 5, 2022 from https://cutt.ly/KMNJoh5.

Sharma, K. (2020, May 7). Government turns to 'TV classrooms' as online lessons prove to be a challenge during lockdown. The Print, 1. Printline Media Pvt. Ltd. Retrieved on March 5, 2022 from https://cutt.ly/DMNv66O.

Shobhit, M. (2020, April). *Technological, social, pedagogical issues must be resolved for online teaching*. Indian Express, 1. Retrieved on March 5, 2022 from https://cutt.ly/IMNcQYh.

Torib, Y. F. (2021, November 17). *Remote learning affects quality of maritime education – official*. The Manila Times. Retrieved on March 4, 2022 from https://cutt.ly/tMNgLQN.

Uğurlu, Ö., Başar, E. & Köse, E. (2012). *Risk analysis of the fire and explosion accidents in oil tankers*. Retrieved on March 5, 2022 from https://cutt.ly/XMNg1gf.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). (2012). *The Philippine Maritime Industry: Prospects and Challenges in 2013 and beyond*. Retrieved on March 5, 2022 from https://cutt.ly/kMNg7M7.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 190–197

ISSN: 1697-4840, www.jmr.unican.es

The impact of the COVID-19 pandemic on the Tunisian La-Goulette port's activity

Rabeb Kammoun[1,*], Chokri Abdennadher[1]

ARTICLE INFO

Article history:
Received 16 Aug 2023;
in revised from 29 Oct 2023;
accepted 22 Dec 2023.

Keywords:
Covid-19 pandemic, the La Goulette port, number of passengers, Consumer Price Index; exchange rate, and the COVID-19 Health Measures Stringency Index.

ABSTRACT

The COVID-19 pandemic has had a globally unprecedented effect on human mobility. In this respect, maritime activities, including passenger traffic, have been significantly impacted by stringent human movement associated restrictions. In this context, the present study is conducted to examine the COVID-19 health crisis implications on maritime passenger traffic, by focusing on the Tunisian La Goulette port undertaken operations. To this end, the Ordinary Least Squares (OLS) method, applying a time series dataset relevant to the period ranging from the first quarter of 2019 to the second quarter of 2023, has been deployed. Our reached findings turn out to reveal that maritime passenger traffic is negatively influenced by both the number of confirmed COVID-19 cases (CAS) and the Consumer Price Index (CPI). Inversely, however, the exchange rate (PRI) and the COVID-19 Health Measures Stringency Index (MSI) appear to display a positive impact on passenger traffic. Such findings are intended to provide ferry companies, cruise operators, and port authorities with valuable insights and guidance to enhance their strategies, thereby, mitigating the impacts of such unpredictable events and shocks as the COVID-19 pandemic.

1. Introduction.

One of the major shocks marking the year 2020 is the worldwide spread of the COVID-19 pandemic and its ensuing impacts on the global economy. Initially sprung in Wuhan, China, by the end of 2019, the COVID-19 deadly virus soon spread to the European Union, America, Africa, and Asia in a mysterious way, which aggravated its effects, leading subsequently to a deteriorating world economy through a sharp decline in investment, production, increased unemployment and social stress.

Certainly, most countries' immediate priority has been to limit the epidemic's repercussions, particularly noticeable though increasing health expenditure to strengthen the health sector's capacities and resources, accounting for the necessary provisions likely to impede and curb the predominance of the pandemic. Hence, human oceanic activities have also been radically altered as a result of the pandemic, with reports of significant port restrictions and shifts in consumption patterns affecting most maritime sectors, including fisheries, passenger ferries and cruise ships, as sectors heavily reliant on the transportation of people and goods. Thus, considering the critical role maritime transport plays in the increasingly expanding global economy, it is estimated that this sector should account for roughly 70% of the world trade value, and for around 80% of its total volume of (Kammoun and Abdennadher, 2022, 2023). As has been the case with most of the previously occurring economic recessions, the COVID-19 pandemic crisis has also been associated with noticeable changes in vessel movement.

Unlike most of the various challenges Tunisia has already encountered over time, the recently witnessed health crisis has had a significantly detrimental impact on the country's economy. Indeed, the COVID-19 pandemic's rapid and extensive spread throughout the country led to the implementation of stringent lockdowns and travel restrictions, adversely effecting most of the global shipping industry interfering areas, including mar-

[1]Department of Competitiveness, Business Decision and Internationalization, Faculty of Management and Economics of Sfax, Tunisia.
[*]Corresponding author: Rabeb Kammoun. E-mail Address: rabebkammoun1989@gmail.com.

itime traffic, trade, container and oil transportation, as well as passenger transport.

Standing out in the western Mediterranean basin, the La Goulette ports represents a major sought-after destinations that serves as a crucial hub, wherein, Tunisia's major road and rail networks converge. Indeed, located in the historically affluent, culturally diverse, and densely populated area that bears its name (La Goulette), which englobes the capital Tunis and its suburbs, it is considered as Tunisia's foremost passenger port. According to the Merchant Marine and Ports Authority's official website 2019 launched statistics, the La-Goulette port accommodated a substantial influx of 857750 passengers, and hosted 323488 ships. In this context, the present study is conducted to examine the Covid-19 health crisis associated repercussions on passenger maritime transport, focusing particularly on the La-Goulette port undertaken operations. To this end, the Ordinary Least Squares (OLS) method, applying a time series dataset relevant to the period ranging from the first quarter of 2019 to the second quarter of 2023, has been used.

This work is organized as follows. Section 2 provides a depiction of the most recently released literature elaborated on the COVID-19 pandemic's impacts on ferry activity. As to Section 3, it provides a thorough depiction of the La-Goulette port, while Section 4 is dedicated to highlighting the methodology applied in our study. Section 5 is devoted to identifying the applied variables and corresponding definitions. As regards Section 6, it involves a discussion of the study reached findings, and the ultimate section bears the major concluding remarks and comments.

2. A literature review on the COVID-19 impact on ferry activity.

Following the unpredicted emergence of the COVID-19 pandemic, the transportation and logistics industry has been faced with significant difficulties and hardships. These challenges have been manifested in various ways, particularly, the imposition of stringent import and export restrictions, a significant decrease in demand for passenger travel, and changes in customer relationships among transportation companies throughout the COVID-19 pandemic prevalence span (Karaman et al., 2020; Mitrega and Choi, 2021).

Worth citing among the research works addressing the COVID-19 pandemic's effects on freight traffic, is the study conducted by Zhou et al. (2022), wherein the authors highlighted the pandemic's serious outcomes on the Shanghai Container Port's operations, stressing the ensuing economic setbacks faced by the port. They also provided some strategic recommendations useful for enhancing recovery. Their reached findings indicate well that significant losses are mainly related to such areas as port dues, handling services, as well as security facility and mooring fees. As for Cariou and Notteboom (2023), they investigated the COVID-19 pandemic's outcomes on the container import flows across the US port distribution network. By applying data relating to more than 21 U.S. ports and tracking over 550000 container shipments via Walmart and Nike, they considered drawing patterns and possible shifts occurring in the U.S. port distribution system. Their attained results turn out to indicate the persistence of several noticeable alterations in distribution channels throughout the pandemic period at both of the aggregated-port as well as specific-industry levels.

At this level, we proceed with examining the literature dealing with the COVID-19's effects on ferry operations. Worth recalling, in this respect, is the study conducted by Depellegrin et al. (2020), who applied a comparative spatio-temporal approach to examine the extent to which national lockdown policies impacted several types of vessels' movement, including fishing vessels, passenger ships, oil tankers, and cargo ships, over the time span ranging from March to April 2020. Their findings revealed a substantial decline in vessel activity during the lockdown period, with a noticeable reduction of 69% compared to the same period of 2017. Accordingly, also, passenger traffic experienced a rather noticeable decline by 78%, while fishing activities demonstrated the most significant reduction, of the rate of 84%, throughout the same period.

On another context, Chen et al. (2022) relied on Automatic Identification System (AIS) based data to analyze the COVID-19 associated effects on passenger transportation in Danish waters. They also examined variations in passenger ship activities and emissions before and after the pandemic's outbreak. Their reached findings recorded significant reductions in SOx emissions, wherein, cruise ships experienced a decrease by 50.71%, ferry-pax vessels by 0.51%, and ferry-ropax vessels by 0.82%. In another study conducted by Smirnov et al. (2022), the authors considered determining the main reasons lying behind the maritime cruise sector's collapse face to the COVID-19 pandemic. Based on statistical data on passenger traffic, revenue and financial results regarding five of the world's largest cruise lines, they noted that the companies' stocks turned out to fall on a daily basis, to record the lowest levels by March 2020. As to Murch et al. (2022), they applied linear mixed-effect model (LMM) to evaluate the containment measures' effects on the noticeable alterations marking the Western Mediterranean marine traffic density, over the first halves of the years 2019 and 2020. Their findings indicated the persistence of a significant decrease, by 70.2%, regarding exclusive economic zones, highlighting that the most substantial global declines took place in April, registering a 1.4% reduction in traffic occupancy, affecting 54.8% of the sample units. They also stressed that passenger ships tended to experience rather significant and enduring declines in traffic patterns. With respect to Mujal-Collilles et al. (2022), they relied the Automatic Identification System (AIS) based real-time data to estimate the COVID-19 pandemic's impact on maritime activity and the ensuing emissions regarding the Barcelona Port, over the period span ranging between March and July 2020. Their attained results proved to demonstrate that during the stringent lockdown period spanning from March to June 2020, a noticeable decrease in maritime passenger traffic was recorded to persist at the Port of Barcelona, coupled with a modest reduction in passenger ship released air pollutant emissions (-1.8% in CO2 emissions).

In turn, and on applying regression models to investigate the pandemic's effects on roll-on/roll-off passenger volume in Finland, Hilmola (2022) concluded that Covid-19 culminated in a

14.9 million loss in passenger volumes, engendering a 1.178 trillion Euros drop in turnover. They outlined that despite government support mechanisms put forward to attenuate the pandemic's impact on passenger volume, the situation did not tend to ameliorate by 2021, and the subsidies continued to be provided, while revenues barely increased and financial profitability was too limited. Similarly, Tapaninen and Palu (2022) documented that the Covid-19 pandemic led to a noticeable decline in passenger volumes regarding the Helsinki and Tallinn bound traffic, resulting in a serious financial problem to shipping companies. As to Maiorov and Fetisov (2022), who used graph modeling techniques to analyze the Covid-19 related effects on the Baltic Sea ferry and cruise routes, they concluded that coupled with the stringent price competition among carriers, the pandemic has remarkably impacted passenger traffic in the region. As regards the Mannarini et al. (2022) conducted study, linear mixed-effect model were applied to examine the COVID-19 impact on European vessel activity throughout the year 2020, to reach the conclusion that a remarkable reduction in unitary CO2 emissions was perceived in 2020, clearly associated with the predominance of the COVID-19 pandemic. This reduction appeared to range between 14% and 31% regarding the largest ferries, denoting a noticeable decline in ferry traffic. The authors also documented that per-ship emissions experienced an extra 18% decrease with respect to the North Sea area.

Thus, based on prior research drawn insights, one could well deduce the existence of an adverse correlation between the COVID-19 health crisis and maritime passenger and ferry traffic. Hence, the need to investigate the outcomes' ramifications of COVID-19 associated impacts on the La-Goulette port maintained operations, as the unique Tunisian port exclusively dedicated to handling passenger and ferry traffic.

3. Overview of the La-Goulette port.

The port is sited in the western Mediterranean region, in the north of Tunisia. Historically, it played a pivotal role in handling most of the country's maritime trade until the mid-1980s. However, since its international trade debut in 1987, the Port has been predominantly focused on handling passenger and cruise ship traffic.

This ferry specializing port draws its importance from the crucial links it maintains with a wide range of destinations, involving the Port of Marseille in France, along with several Italian ports including Civitavecchia, Genoa, Salerno, and Palermo in Sicily. Most often, cruise tourists disembark at the La-Goulette port, wherein, they have the opportunity to explore the tourist village of La Goulette, typically renowned for the wide range of Tunisian handicraft specificities it offers. They could also visit the historical Medina site of Tunis as well as various archaeological monuments.

In effect, the port of La-Goulette keeps maintaining bustling operations and activities not only during the full summer season, but also round the year, particularly during the periods spanning from late December to the end of January and the vacation-season weeks abroad, characterized with a significant influx of travelers. Moreover, the port stands as the primary access point for an annual average number of 50000 vehicles, while playing a pivotal role in facilitating the reception of Tunisian car dealers' imported automobiles.

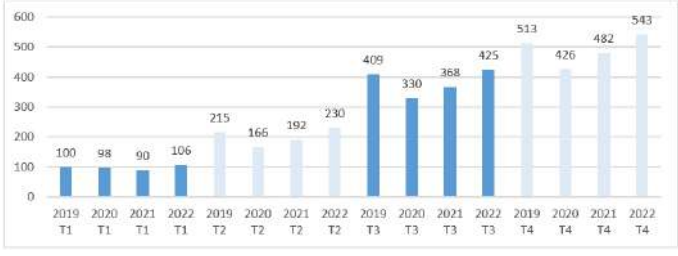
As the year 2020 was marked with an unprecedented health crisis, namely, the widespread of the Covid-19 pandemic, maritime transport encountered significant challenges relating to the implementation of various health-crisis combating measures, including lockdowns, curfews, non-essential business closures, travel restrictions, and others. The relevant impacts were particularly pronounced during the lockdown early stages, initially effective in Tunisia ever since March 13, 2020. In this respect, the Tunisian maritime transport sector started to experience the pandemic associated repercussions, marked with a severe economic slowdown along with the adoption of containment measures by several countries. Above all, the year 2020 was marked with the widespread of the Covid-19 global health crisis.

Based on the Office of Merchant Marine and Ports (OMMP) authority released data, the COVID-19 pandemic had a significant impact on the Tunisian maritime transport sector. In 2020, the number of individual sea travelers noticeably decreased, substantially by 56%, registering a total number of 342111 passengers recorded at the Tunisian access ports, according to the OMMP maintained records. Similarly, the OMMP recorded a 6% reduction in the number of hosted vessels, with only 1020 ships registered for entry at the La-Goulette port during 2020.

Figure 1: Evolution in passenger-traffic volumes from the first quarter of 2019 to the fourth quarter of 2022.

Source: OMMP.

Figure 2: Evolution in vessel traffic from the first quarter of 2019 to the fourth quarter of 2022.



Source: OMMP.

4. Methodology.

Our pursued econometric methodology involves expressing a particular phenomenon's specific behavior by means of equa-

tions, along with an estimation of these equations drawn coefficients through historical data specific to that phenomenon. Such an approach has been adopted for the sake of effectively comprehending, elucidating, replicating, and predicting the relevant phenomenon.

Hence, the ordinary least squares (OLS) approach, fit for implementation in this particular context, designates the mathematical regression technique frequently used in statistics, more specifically, in the linear-regression econometrics, requiring the alignment of a scatterplot of data points, represented as (Y, X), via a linear relationship.

In its full sense, an ordinary Least Squares (OLS) model estimation proceeds with minimizing the sum of squared differences between the recorded values and the predicted values. Such a procedure is undertaken to define the optimal coefficients enabling to effectively capture the variables binding relationship. It is worth noting that a simple linear regression model involves selecting key variables of two main types, i.e., a dependent variable (Y) and an independent one (X). Thus, an OLS estimation is designed to retrieve the regression line that minimizes the squares' sum of the deviations between the actual values of Y and the regression line predicted values. Hence, within a multiple linear regression framework, there should figure several independent variables (X1, X2, X3, etc.) along with a single dependent variable (Y). OLS estimation seeks to determine the most optimal coefficients fit for each independent variable, thereby, achieving a multiple linear model that provides the most accurately effective explanation of the dependent variable associated variability. This relationship is depicted as follows:

$$Y_t = \alpha + \beta_1\, CAS_t + \beta_2\, MSI_t + \beta_3\, PRI_t + \beta_4\, CPI_t + \lambda_t + \varepsilon_t \quad (1)$$

Where:

t designates the temporal index; α stands for an unknown constant; β denotes the independent variables' regression coefficient; Y_t stands for the dependent variable, denoting the La-Goulette port passenger traffic; CAS presents the number of confirmed cases; MSI denotes the COVID-19 Health Measures' Stringency Index; CPI designates the consumer price index; : PRI stands the TND-EUR exchange price; while, λ_t stands for the time-effects, and ε_t designates the error term.

The OLS modeling estimation process entails assessing a selection of hypotheses to ensure the attainment of a Best Linear Unbiased Estimator (BLUE) model. Such a procedure requires validating a set of relevant hypotheses in terms of:

- Normality of errors: assessing the normality of errors involves comparing asymmetry statistics among various models;
- Absence of errors relating autocorrelation;
- Homoscedasticity of errors.

Actually, validating these three hypotheses require constructing a robust model, enabling to attain reliably interpretable results.

5. Applied data.

To analyze the COVID-19 pandemic's effect on the La - Goulette port's operations, we have proceeded with collecting relevant data regarding the time period spanning from the first quarter of 2019 to the second quarter of 2023. In this context, passenger traffic (Y) are used as dependent variable. The relevant datasets have been outsourced from the official OMMP authority's website. In addition, four specific explanatory variables have also been selected, based on data availability, namely:

(a) The COVID-19 Health Measures' Stringency Index (MSI): initially established by the University of Oxford, this variable should serve to estimate the stiffness and strictness level of the public health measures and popular activities curtailing policies. This index represents a semi-quantitative metric englobing data from nine distinct public health interventions, involving such measures as school and workplace closures, public events' canceling, gatherings' sizes imposed limits, public transportation shut downs, home-stay implementation orders, domestic mobility regulations (within a country, province, or territory), international travel stringent control, and setting up public sensitization campaigns. Accordingly, a high MSI score should denote a highly rigorous response to the pandemic, wherein, a score of 100 reflects the most stringent measures being adopted and established. Initially implemented by Xu et al. (2020), this variable has been outsourced from the Tunisian Health Ministry's official website.

(b) The Number of confirmed cases (CAS): it is a metric measure that denotes the total number of Tunisian individuals positively tested for COVID-19. It stands as a key indicator reflecting the seriousness extent of the COVID-19 outbreak in the country. This data item has been widely referenced and utilized by various researchers, worth citing among whom are Mujal-Collilles et al. (2022) and Hilmola (2022). The relevant data have been directly downloaded from the official the Tunisian Health Ministry's website.

(c) The Consumer Price Index (CPI): it designates a macroeconomic variable that represents the main economic indicator used to track a particular country's inflation rate and living cost. It englobes a basket of goods and services, whereby, the basket price is computed in terms of the weighted average of the constituent items' retail prices. Applied by Xu et al. (2020), this variable has been drawn from the official Tunisian statistics agency's special website.

(d) The TND-EUR (PRI) exchange price: it stands for a macroeconomic variable, which is determined either as a valuation of a nation's country, or as other payers' issued loan. Initially applied by De Leon et al. (2009), the variable has been downloaded from the "Investing.com" website.

Our Ordinary least squares (OLS) modeling procedure has been conducted to estimate the primary factors influencing the La-Goulette port's operational performance throughout the COVID-19 pandemic predominance span, wherein, passenger traffic (Y) stands as a port productivity estimating indicator. Table

Table 1: The applied variables' descriptive statistics.

Variable	Obs	Min	Max	Mean	STD
Y	18	21922	397276	160607.8	134336.1
CAS	18	0	38371	7203.667	12007.36
MSI	18	0	97.63	46.07833	32.322
PRI	18	3.143	3.414	3.259	0.076
CPI	18	122.233	166.3	140.231	13.656

Source: Authors.

Table 2: The applied variables corresponding correlation coefficients.

	Y	CAS	MSI	PRI	CPI
Y	1.000				
CAS	-0.252	1.000			
MSI	0.382	0.448	1.000		
PRI	0.285	0.080	-0.215	1.000	
CPI	-0.129	0.021	0.090	0.296	1.000

Source: Authors.

1 provides a depiction of the applied variables corresponding descriptive statistics. As for Table 2, it displays the relevant correlation coefficients, wherein, the entirety of the coefficients turn out to be inferior to 0.5, affirming the absence of any multicollinearity problems among the selected variables.

For the purpose of estimating the determinants influencing the La-Goulette port's performance against the backcloth of the COVID-19 pandemic, we consider implementing the time-effects enclosing OLS approach. The administered analysis major attained findings have been achieved by means of Stata software, as highlighted in the section below.

6. Results.

6.1. Estimation and Results of the ordinary least squares modeling method.

An initial examination of the Stata 15 output reveals well that the model tends to demonstrate a noticeable overall significance. In effect, an 82% R-squared and an adjusted R-squared of 81% of the model's remarkable fit for implementation with the regression analysis selected data have been recorded. This is further substantiated by the Fisher statistic's specific probability, falling below the error threshold of 5%. In addition, the Durbin-Watson statistic, falling within the range of 0 to 4 and of a value rate of 2.007, highlights well the absence of autocorrelation within the sample, testifying well our pursued regression model's high performance and appropriate validity.

Table 3: Regression reached results.

Variables	Coefficient	P-value
CAS	-214.879	0.000***
MSI	188.379	0.017**
PRI	354.212	0.016**
CPI	-649.462	0.006***
T2 (2019)	263.186	0.017**
T3 (2019)	1.629	0.036**
T4 (2019)	204.62	0.033**
T1 (2020)	-188.647	0.101
T2 (2020)	-0.001	0.000***
T3 (2020)	-1.335	0.023**
T4 (2020)	-0.190	0.947
T1 (2021)	-188.379	0.023**
T2 (2021)	-34.286	0.042**
T3 (2021)	-78.647	0.007***
T4(2021)	26.359	0.037**
T1 (2022)	17.411	0.016**
T2 (2022)	14.532	0.031**
T3 (2022)	40.389	0.011**
T4(2022)	24.340	0.040**
T1 (2023)	54.367	0.042**
T2 (2023)	19.466	0.020**
CST	226.359	0.019**
R-squared		0.820
Adj R-squared		0.810
Prob (F-statistic)		0.002
Durbin -Watson		2.007
N		18
The significance thresholds are respectively set at: 1% (***), 5% (**) and 10% (*).		

Source: Authors.

Accordingly, the achieved findings turn out to indicate that maritime passenger traffic has actually been negatively affected by the number of COVID-19 confirmed cases (CAS). Indeed, a notable gap in passenger traffic has been recorded, dwindling down from 106714 passengers, throughout the second quarter of 2019, to 28377 passengers, during the second quarter of 2020, marking the pandemic onset. At this level, and with the rising numbers of confirmed COVID-19 cases, travelers began to grow rather superstitious, health caring and safety apprehensive. As a matter of fact, the fear of attaining the Corona virus infection risks while on a maritime trip has certainly dis-

couraged people to travel, therefore, traffic has been noticeably reduced. Furthermore, the rising figures of COVID-19 infected cases' might well undermine the maritime passenger confidence in travel associated activities. Indeed, passengers are most often unwilling to make any travel plans or bookings once uncertain about the predominant sanitary situation, thereby, maritime passenger traffic turns out to be declined. On the other hand, maritime transport suppliers might also be faced with the Covid pandemic related operational rules and constraints, including, reduced schedules, capacity limitations, implementation of imposed health protocols and vaccination requirements, thereby, restricting traveling operations while discouraging potential travelers.

Negatively correlated with maritime passenger traffic, a rise in Consumer Price Index (CPI) is usually associated with significant increases in good and service prices throughout a particular time period. As a sign of inflation, it designates a general increase in living costs within a specific economy, clearly manifested in a reduced currency purchasing power, therefrom, effectively decreasing the quantity of services and merchandises one could purchase with the same quantity of money. With respect to the tourism area, however, a higher CPI would also affect the tourists' purchasing potential, whose income and savings might well fail to cope with rising inflation, thus, being faced with shrinking leisure devoted income, mainly, travel. Therefore, not only the number of tourists would shrink, but also their visits allocated budget. Hence, in situations of price-escalation due financial constraints, consumers would often opt for cutting in discretionary expenditures, including leisure travel activities. This provides a plausible explanation of the maritime passenger traffic descending trend, which went down from 324469, in the third quarter of 2019, to 126934, in the third quarter of 2020. Such a noticeable decrease in the number of passengers was coupled with an increase in Consumer Price Index (CPI), going up from 125.633, in the third quarter of 2019, to 134.366, in the third quarter of 2020.

Additionally, the attained results turn out to reveal the persistence of a positive correlation between the exchange rate (PRI) and passenger traffic, particularly regarding the Tunisian Dinar (TND) versus the Euro (EUR) exchange rate context. Such a relationship is mainly due to the significant effect of currency exchange costs highly affecting maritime passenger traffic in Tunisia, and reflecting special economic impacts. In fact, the Tunisian Dinar (TND) exchange level might well make of Tunisia a rather low-price resort for Europeans, likely to perceive Tunisia as a highly attractive travel option, owing mainly to the Euro's higher exchange rate relative to the TND. Similarly, the Euro/Dinar differential exchange rate is another factor maintaining the fact that the hostelry and restauration sector, along with other local businesses turn out to offer competitive prices in relation to several other countries' provided costs, thereby, representing a rather attractive destination for visitors. Hence, the TND and EUR binding exchange rate dynamics would actually have remarkable impacts on Tunisia's maritime travel industry. In effect, a rather favorable exchange rate level, could well provide greater impetus to maritime passenger traffic inflows, thereby, enhancing not only the tourism industry, but also the national economy as a whole. Actually, a boost in maritime passenger traffic would be highly beneficial not only for the ferry companies, but also for cruise operators, port services, and the relating businesses, with promising increased revenues and positive potentials for the employment sector.

The achieved results also indicate the existence of a positive correlation binding the COVID-19 Health Measures Stringency Index (MSI) and the number of passenger. Indeed, a high (MSI) Index denotes well that Tunisia has undertaken to implement stringent public health policies in a bid to stop the propagation of the COVID-19 pandemic. In effect, such an association might well have it justification in the fact that an elevated MSI is but the result of stiff testing and safety measures, intended to reassure and heighten traveler confidence, and therefore, should not necessarily culminate in a declining maritime passenger traffic. Thus, on perceiving Tunisia as a safe destination with a wide range of safety and sanitary guarantees being put in place, certain travelers would not feel inclined to visit it, thereby, maintaining sea passenger traffic stability, or even boosting its status. Such a trend is particularly important in the case high travel demand circumstances, even in presence of stiff pandemic-related restriction measures. Throughout the third quarter of the year 2020, for instance, the COVID-19 related MSI index proved to record a threshold of 49.07, in return for a passenger score of 126934 travelers. Inversely, however, during the third quarter of 2021, with the COVID-19 Health Measures Stringency Index (MSI) hitting the threshold of 79.63, a significant improvement in passenger figures has been scored, recording a ceiling of 245811 travelers. Such findings tend to corroborate the results published by Xu et al. (2020).

Starting from the fourth quarter of 2021, however, positive and statistically significant temporal effects were recorded, as an outcome of effective governance and the professional medical staff's unwavering joint commitment, displaying a remarkable role in gradually attenuating and combatting the prevailing pandemic. It is actually thanks to these combined factors that the health situation started to consistently demonstrate a noticeable improvement, leading the La-Goulette port to recover and resume its normal frequent activities. As a matter of fact, such an achievement highlights well the high efficiency associated with the undertaken crisis-management measures, as well as the healthcare sector's endurance, capacity and willingness to confront and curb such unparalleled sanitary challenges.

6.2. Model validation.

For an effective assessment of the Ordinary Least Squares (OLS) model's robustness, and to pinpoint any potential residuals associated problems, likely to emanate within the OLS regression context, a selection of diagnostic tests have been administered. In this regard, the Jarque-Bera test has been administered to evaluate the residuals' normality level, while the White test has been conducted to detect the existence of any heteroscedasticity problems. As to the Breusch-Godfrey test, it has been applied to identify any autocorrelation issue. The tests achieved results, administered to control for any presumed residuals, are depicted on the table below.

Table 4: The diagnostic (Bera, White, and Breusch-Godfrey) tests reached results.

	Statistic	Probability
Jarque-Bera test	0.789	0.638
White test	13.74	0.469
Breusch-Godfrey test	0.106	0.936

Source: Authors.

As illustrated through Table 4, the diagnostic tests' results appear to reveal that the Jarque-Bera test attained probability value turns out to be of the rate of 0.638, exceeding the threshold of 0.05, therefore, the residuals prove to follow a normal distribution at a significance level of 5%. Similarly, the White's test probability value is of the rate of 0.469, which clearly exceeds the threshold of 0.05, highlighting the absence of any heteroscedasticity problem in our applied model within a significance level of 5%. As regards the Breusch-Godfrey test reached probability value, it has been equal to 0.936, clearly exceeding the threshold of 0.05, indicating the absence of any inter-residual serial correlations at a significance level of 5%. Thus, based on the table provided results, the entirety of administered tests turn out to testify the applied model's robust nature. Accordingly, the validation tests drawn probabilities tend to support the BLUE (Best Linear Unbiased Estimator) model advanced core hypothesis, thereby, maintaining a high confidence level regarding the robustness of the present analysis drawn interpretations.

Conclusions

The present research is conducted to explore the COVID-19 health crisis impact on the current status of the Tunisian La-Goulette seaport, uniquely specializing in passenger maritime transport. To this end, the OLS model has been applied to analyze a time series spanning from the first quarter of 2019 to the second quarter of 2023.

A comprehensive analysis of the findings achieved turns out to reveal the persistence of a negative effect of the COVID-19 pandemic on the maritime sector. The number of confirmed COVID-19 attained cases has been discovered to display a negative correlation with passenger shipping traffic, thereby, corroborating the Xu et al. (2020) released findings. In addition, the study also demonstrates that the Consumer Price Index (CPI) tend to be negatively associated with maritime passenger traffic. Indeed, increasingly ascending CPI could only dissuade tourists and passengers from targeting Tunisia as a desirable destination.

Noteworthy, however, is that the attained results prove to indicate the existence of a positive correlation between the COVID-19 Health Measures Stringency Index (MSI) and the number of passengers, highlighting that Tunisia's stringent COVID-19 pursued containment measures turned out to draw and attract massive passengers. Such findings tend to corroborate the results published by Xu et al. (2020). Additionally, the achieved results also reveal that the high Euro-TND exchange rate (PRI) levels contribute in boosting passenger traffic, making of Tunisia a rather cost-effective resort for European travelers, likely to consider Tunisia a rather attractive destination, accounting for the Euro's increased purchasing rate in relation to the TND.

Ultimately, one might well draw attention to a major limitation likely to be associated with this study, namely, its exclusive focus on the La-Goulette seaport of Tunisia, which has been mainly due to the unavailability of the neighboring countries' seaports relevant data. Hence, a potential research study venue could expand the research line so as to examine the effect of the COVID-19 pandemic's impacts on goods traffic, at an international scale level.

References.

Cariou, P., & Notteboom, T. (2023). "Implications of COVID-19 on the US container port distribution system: import cargo routing by Walmart and Nike." International Journal of Logistics Research and Applications, 26(11), 1536-1555.

Chen, Q., Ge, Y., Lau, Y., Dulebenets, M. A., Sun, X., Kawasaki, T., Mellalou, A., & Tao, X. (2023). "Effects of COVID-19 on passenger shipping activities and emissions: empirical analysis of passenger ships in Danish waters". Maritime Policy & Management, 50(6), 776-796.

De Leon, M., Fullerton Jr, T. M., & Kelly, B. W. (2009). "Tolls, Exchange Rates, and Borderplex International Bridge Traffic." International Journal of Transport Economics, 36(2).

Depellegrin, D., Bastianini, M., Fadini, A., & Menegon, S. (2020). "The effects of COVID-19 induced lockdown measures on maritime settings of a coastal region". Science of the Total Environment, 740, 123-140.

Hilmola, O. P. (2022). "Ropax Short-Sea Shipping and Covid-19 Pandemic: Case of Finland". International Journal of Maritime Affairs and Fisheries, 14(1), 91-114.

Kammoun, R., & Abdennadher, C. (2022). "Seaport efficiency and competitiveness in European seaports". Transport Policy, 121, 113–124.

Kammoun, R., & Abdennadher, C. (2023). "Determinants of seaport efficiency: An Analysis of European container ports". Journal of Maritime Research, 20(1), 145–158.

Karaman, A. S., Kilic, M., & Uyar, A. (2020). "Green logistics performance and sustainability reporting practices of the logistics sector: The moderating effect of corporate governance". Journal of Cleaner Production, 258, 120718.

Maiorov, N., & Fetisov, V. (2022). "Research and Forecasting of Changes in Baltic Sea Ferry and Cruise Routes". Transportation Research Procedia, 61, 392-397.

Mannarini, G., Salinas, M. L., Carelli, L., & Fasso, A. (2022). "How COVID-19 Affected GHG Emissions of Ferries in Europe". Sustainability, 14(9), 52-87.

March, D., Metcalfe, K., Tintoré, J., & Godley, B. J. (2021). "Tracking the global reduction of marine traffic during the COVID-19 pandemic". Nature Communications, 12(1), 15-24.

March, D., Metcalfe, K., Tintoré, J., & Godley, B. J. (2021). "Tracking the global reduction of marine traffic during the COVID-19 pandemic". Nature Communications, 12(1), 15-24.

March, D., Metcalfe, K., Tintoré, J., & Godley, B. J. (2021). "Tracking the global reduction of marine traffic during the COVID-19 pandemic". Nature Communications, 12(1), 15-24.

Mitrkega, M., & Choi, T.-M. (2021). "How small-and-medium transportation companies handle asymmetric customer relationships under COVID-19 pandemic: A multi-method study". Transportation Research Part E: Logistics and Transportation Review, 148, 102249.

Mujal-Colilles, A., Guarasa, J. N., Fonollosa, J., Llull, T., & Castells-Sanabra, M. (2022). "COVID-19 impact on maritime traffic and corresponding pollutant emissions. The case of the Port of Barcelona". Journal of Environmental Management, 310.

Mujal-Colilles, A., Guarasa, J. N., Fonollosa, J., Llull, T., & Castells-Sanabra, M. (2022). "COVID-19 impact on maritime traffic and corresponding pollutant emissions. The case of the Port of Barcelona". Journal of Environmental Management, 310, 114787. ISSN 0301-4797.

Pillai, N., & Vijayamohanan (2016). "Panel Data Analysis with Stata Part 1: Fixed Effects and Random Effects Models". MPRA Paper 76869, University Library of Munich, Germany.

Smirnov, A., Smyaglikova, E., Smolokurov, E., & Mazhazhikhov, A. (2022). " COVID-19 Pandemic Impact on Maritime Cruise Industry". E3S Web of Conferences, 363.

Tapaninen, U., & Palu, R. (2022). "Recovery of ro-pax ferry traffic from COVID-19 under tightening environmental regulations: case Helsinki-Tallinn". Journal of Shipping and Trade, 7(10).

Zhou, X., Dai, L., Jing, D., Hu, H., & Wang, Y. (2022). "Estimating the economic loss of a seaport due to the impact of COVID-19". Regional Studies in Marine Science, 52, 102258. ISSN 2352-4855.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 198–208

ISSN: 1697-4840, www.jmr.unican.es

The role of mental image and the relationship between service quality and customer satisfaction in Jordanian telecom companies

Yahia Alajaleen[1,*], Dr. Mohd Saiful Saadon[1], Qais Albtoosh[1], Yahia Alqaise[1], Mohammad Ziad Alkfaween[1]

ARTICLE INFO

Article history:
Received 9 Sep 2023;
in revised from 10 Sep 2023;
accepted 2 Oct 2023.

Keywords:
mental image, service quality, customer satisfaction.

ABSTRACT

This study aims to achieve several objectives that contribute to understanding the role of mental image in the relationship between service quality and customer satisfaction in Jordanian telecom company's and Analysis of the relationship between service quality and customer satisfaction: The study seeks to understand the relationship between the quality of service provided by Jordanian telecom companies and the level of customer satisfaction with it. The literature on quality and satisfaction will be reviewed to determine the link between them and its impact on the company's mental image. A descriptive analytical research method was adopted for the sake of the current study.
The results revealed:
- Mental image influences the satisfaction of telecommunications companies in Jordan) with an arithmetic mean 4.475 and a standard deviation 0.650, In the last ranking (mental image of companies in the telecommunications) with an arithmetic mean 4.280 and a standard deviation 0.696.
- As it is clear that the general mean of the dimension reached its Value 4.300, the value is high on the Likert scale.
- In the first ranking (enhance our understanding of the role of mental image and improve service quality and customer satisfaction in Jordanian telecom companies) with an arithmetic mean 4.490 and a standard deviation 0.633, In the last ranking (Mental imagery is often used interchangeably with the term 'mental image') with an arithmetic mean 4.160 and a standard deviation 0.621.
- As it is clear that the general mean of the dimension reached its Value 4.305, the value is high on the Likert scale.

1. Introduction.

Jordan's telecom industry is a crucial and significant part of the country's economy. Through technology and ongoing innovation, these businesses play a significant role in delivering communication services to individuals and businesses in order to fulfil their expanding demands in a world that is continuously changing. The standard of service rendered in this context is one of the key element's users seek for. (Alamgir & Shamsuddoha, 2015, p178).

The quality of service is a critical element in customers' evaluation of the telecom company's performance and its dealings with them. When the customer finds a reliable and effective service, it leaves a positive impression on the company, and thus they feel satisfied and confident in what this provider provides them with communication services. Hence, the role of the mental image in enhancing or undermining the relationship between service quality and customer satisfaction. (Chen& Popovich,2003, p89).

A mental image refers to the beliefs, impressions, and feelings that customers have about a company. When the customer has a positive mental image towards the company, he has high expectations about the quality of service, and this increases the possibility of achieving customer satisfaction. Conversely, if the company's mental image is negative, this is likely to nega-

[1]Universiti Malaysia Terengganu.
[*]Corresponding author: Yahia Alajaleen. E-mail Address: yahia.ajaleen@yahoo.com.

tively affect customers' evaluation of service quality and lead to a deterioration in their satisfaction. (Chen & Ching,2007, p70).

Therefore, this study aims to explore and understand the role of mental image in the relationship between service quality and customer satisfaction in Jordanian telecom companies. We will focus on analyzing the interrelationship between service quality and mental image, and how they affect customer satisfaction. We will also study the factors affecting the formation of the company's mental image and how they affect customers' evaluation of service quality and their final level of satisfaction. (Asgari & Omrani,2016, p56).

The findings and recommendations from this study will be used to enhance our understanding of the role of mental image and improve service quality and customer satisfaction in Jordanian telecom companies, thus supporting continuous development and improvement in this vital sector. (Alshurideh, Gasaymeh, Ahmed, Alzoubi & Kurd, 2020, p67).

2. Problem of study.

Jordanian telecom companies face great challenges in achieving satisfactory quality of service and customer satisfaction. One of the main problems that these companies face is the relationship of the mental image between service quality and customer satisfaction. The research problem emerges from crossing over from the theoretical and conceptual aspects of this topic to the practical induction and analysis of the effect of the mental image on the Jordanian telecommunications companies. (Jones, & Suh, 2001, p189).

And the possibility of a negative mental image of customers towards these companies may be reflected in their evaluation of the quality of service and their personal experience, which ultimately leads to a decrease in their level of satisfaction and possibly their loss as customers. Moreover, multiple challenges may arise in shaping the optimal corporate image, including communications, effective marketing, and outstanding customer service.

Hence, the importance of studying the role of the mental image in the relationship between service quality and customer satisfaction in the Jordanian telecommunications companies, as this study contributes to enhancing our understanding of the impact of the mental image on the probability of achieving customer satisfaction and working to improve service quality based on practical analyses and conclusions. (Gates, 2010, p97).

By highlighting this problem, the study will contribute to identifying weak points and potential improvements in service delivery, thus achieving customer satisfaction and building a positive mental image for Jordanian telecom companies.

3. Research importance.

Studying the role of the mental image in the relationship between service quality and customer satisfaction in Jordanian telecom companies is of great importance, for the following reasons:

Enhancing Customer Satisfaction: Customer satisfaction is one of the most important indicators of the success of any company. When customers are satisfied with the quality of service they receive, their level of satisfaction increases and loyalty to the company increases. Hence, continuous profits and sustainable growth of the company increases.

Improving the company's reputation: The company's positive mental image contributes to building its reputation and strengthening its position in the Jordanian telecommunications market. When customers create a positive perception of a company, it can lead to increased reliability and trust from consumers, investors and business partners.

Enhancing competitiveness: Providing high quality of service and achieving customer satisfaction can be a strong competitive advantage for telecom companies in the Jordanian market. When customers have a positive experience and are satisfied with the service, they tend to stay with that company rather than switch to competitors. Thus, the company can achieve a competitive advantage and increase its market share.

Directing improvements and development: By understanding the impact of image on service quality and customer satisfaction, Jordan Telecom companies can identify weaknesses and improve aspects of service that may negatively affect customers' image. Thus, future improvements and developments can be directed to enhance the quality of service and raise the level of customer satisfaction.

In short, understanding and analyzing the role of mental image in the relationship of service quality and customer satisfaction in Jordanian telecom companies helps to achieve customer satisfaction, build a positive image of the company and enhance its competitiveness in the market.

4. Research aims.

This study aims to achieve several objectives that contribute to understanding the role of mental image in the relationship between service quality and customer satisfaction in Jordanian telecom companies. The following are the most important objectives that can be achieved through this study:

Analysis of the relationship between service quality and customer satisfaction: The study seeks to understand the relationship between the quality of service provided by Jordanian telecom companies and the level of customer satisfaction with it. The literature on quality and satisfaction will be reviewed to determine the link between them and its impact on the company's mental image.

Studying the mental image of the company: The study aims to understand how the mental image of the company is formed in the minds of customers and the extent of its impact on their evaluation of the quality of service and their satisfaction. Factors influencing the formation of the mental image, such as marketing, communications and previous customer experiences, will be analysed.

Identifying factors for improving service quality: The study will contribute to identifying factors that can be improved to enhance the quality of service provided by Jordanian telecommunications companies. Customer experiences will be analyzed

and their opinions will be surveyed to identify areas that can be improved and developed to achieve a high level of service quality.

Make Recommendations for Improvement: The study will provide practical and concrete recommendations to Jordanian telecom companies based on the results and analyses. Recommendations will focus on how to enhance the company's corporate image, improve service quality, and increase customer satisfaction. These recommendations will be valuable tools for improving performance and enhancing competitiveness in the Jordanian telecom market.

By achieving these objectives, the study contributes to enriching knowledge about the role of mental image in service quality and customer satisfaction in Jordanian telecom companies, and providing practical directions for improving performance and enhancing customer experience.

5. Research questions.

What is the effect of the mental image of the Jordanian telecom companies on customers' evaluation of service quality?
Does the quality of service provided by the Jordanian telecom companies affect the formation of the mental image of customers?
What are the factors affecting the formation of the mental image of companies in the telecommunications sector in Jordan?
Is there a bilateral relationship between the mental image and customer satisfaction in the Jordanian telecom companies?
How can service quality be improved and a positive mental image for Jordanian telecom companies to enhance customer satisfaction?
In light of the questions raised about the subject of the research and in the hope of achieving the objectives of the research, a set of hypotheses can be identified as follows:
The main hypothesis: There is a significant effect between service quality and customer satisfaction in Jordanian telecom companies $\alpha \leq .05$.

- **Hypothesis 1**: There is a positive relationship between service quality and customer satisfaction in Jordanian telecom companies.

- Commentary: The data analysis showed a small positive correlation between service quality and customer satisfaction in Jordanian telecom companies. This suggests that improvements in service quality making might be associated with better implementation of customer satisfaction in Jordanian telecom companies. However, the correlation was not strong, indicating that other factors might also be influencing customer satisfaction in Jordanian telecom companies

- **Hypothesis 2**: There is a positive relationship between service quality and customer satisfaction in Jordanian telecom companies.

- Commentary: The data analysis showed a small positive correlation between service quality and l customer satisfaction in Jordanian telecom companies This suggests that companies with better service quality. However, as with the first hypothesis, the correlation was not strong, indicating that other factors might also be influencing service quality and customer satisfaction in Jordanian telecom companies.

- **Hypothesis 3**: There is no significant relationship between service quality and customer satisfaction in Jordanian telecom companies.

6. Literature review.

6.1. The relation between Mental Image and its Importance in Understanding Customer Behavior.

A mental image is a representation of something in the mind, such as a person, place, or object. It can be visual, auditory, or even tactile. Mental images are important in understanding customer behavior because they can influence how customers perceive a company and its products or services. (Alipour & Mohammadi, 2011, p149).

For example, if a customer has a positive mental image of a company, they are more likely to be loyal to that company and to recommend its products or services to others. Conversely, if a customer has a negative mental image of a company, they are more likely to switch to a competitor. (Alamgir & Shamsuddoha, 2015, p178).

There are a number of factors that can affect the formation of a customer's mental image of a company. These factors include:

- Personal experiences: Customers' personal experiences with a company can have a big impact on their mental image of that company. For example, if a customer has a positive experience with a company's customer service, they are more likely to have a positive mental image of the company overall. (Alamgir & Shamsuddoha ,2015, p167).

- Word-of-mouth: Word-of-mouth from other customers can also influence a customer's mental image of a company. If a customer hears positive things about a company from their friends or family, they are more likely to have a positive mental image of that company. (Mishra, Sinha& Singh, 2014, p146).

- Company advertising: A company's advertising can also influence a customer's mental image of that company. If a company's advertising is effective, it can help to create a positive mental image of the company in the minds of consumers. (Malhotra, & Birks, 2006, p146).

- Company branding: A company's branding can also influence a customer's mental image of that company. A well-branded company will have a clear and consistent image in the minds of consumers. (Lingavel, 2015, p190).

6.2. Factors Affecting the Formation of the Mental Image of the Company.

The mental image of a company is a complex construct that is influenced by a variety of factors. Some of the most important factors include: (Khaligh, Miremadi, and Aminilari, 2012, p129), (Jones, & Suh, 2001, p189).

- Product quality: The quality of a company's products or services is one of the most important factors that affects its mental image. Customers are more likely to have a positive mental image of a company that offers high-quality products or services.
- Customer service: The quality of a company's customer service is also an important factor that affects its mental image. Customers who have positive experiences with a company's customer service are more likely to have a positive mental image of that company.
- Company reputation: The reputation of a company is another important factor that affects its mental image. Companies with a good reputation are more likely to have a positive mental image than companies with a bad reputation.
- Company branding: The branding of a company is also an important factor that affects its mental image. Companies with strong branding are more likely to have a positive mental image than companies with weak branding.

In Jordan, the telecommunications industry strives to provide high-quality services to its customers. The telecom sector in the country places significant emphasis on delivering reliable and efficient communication solutions. Jordanian telecom companies prioritize the provision of superior service quality to ensure customer satisfaction. (Hayati, Suroso, Suliyanto, & Kaukab, 2020, p139)

The telecom industry in Jordan is dedicated to meeting the growing demands of the market while maintaining a high level of service quality. Service providers continually invest in advanced technologies and infrastructure to enhance their offerings. This commitment enables them to deliver seamless connectivity, improved network coverage, and faster data speeds to their customers. (Haridasan, & Venkatesh, 2011, p90)

Jordanian telecom companies also place great importance on customer support and responsiveness. They understand the significance of promptly addressing customer concerns and ensuring effective communication channels. With a focus on customer satisfaction, they strive to resolve issues efficiently, provide accurate information, and maintain open lines of communication. (Greenberg, 2004, p53)

Furthermore, telecom regulatory authorities in Jordan play a crucial role in ensuring quality standards are met. They establish and enforce regulations that promote fair competition, quality of service, and consumer protection. These regulations contribute to fostering a healthy and competitive telecom market, ultimately benefiting customers by encouraging service providers to maintain high-quality standards. (George, & Mallery, 2003, p97)

In general, telecommunications services in Jordan are not characterized by providing high quality, reliable connectivity, and responsive customer support. The continuous investments in infrastructure, technological advancements, and adherence to regulatory standards collectively contribute to the provision of high-quality telecom services in the country. (Gefen, & Ridings,2002, p97)

6.3. The relation between quality of service and its various dimensions in the telecommunications sector.

Quality of service (QoS) in the telecommunications sector refers to the overall performance and characteristics of the services provided to customers. It encompasses various dimensions that assess different aspects of service delivery.

One dimension of service quality is reliability, which refers to the ability of the telecommunication network to consistently provide uninterrupted connectivity and service availability. A reliable network ensures minimal disruptions and downtime, leading to enhanced customer satisfaction. (Gates, 2010, p97).

Another dimension is network coverage, which evaluates the extent and effectiveness of signal coverage provided by the telecom operator. A wide and efficient coverage area enables customers to access services in various locations, both urban and rural, ensuring equal opportunities for connectivity. (Ganiyu, Uche & Adeoti, 2012, p143).

Speed and performance form another crucial dimension. It measures the data transmission speed, response time, and overall efficiency of the network. Faster speeds and low latency are highly valued by customers, as they enable seamless browsing, video streaming, and other data-intensive activities. (Croteau & Li, 2009, p189).

Additionally, customer support is a significant dimension of service quality. It encompasses the responsiveness, efficiency, and effectiveness of the telecom operator's customer service department in addressing customer queries, resolving issues, and providing accurate information. Prompt and satisfactory customer support plays a vital role in ensuring customer satisfaction and loyalty. (Choi & Wan, 2013, p154).

Service affordability is yet another dimension that evaluates the pricing and cost-effectiveness of telecom services. Customers expect reasonable and competitive pricing plans that offer value for money. Affordability, combined with service quality, influences customer satisfaction and their perception of the overall value received. (Alamgir & Shamsuddoha, 2015, p178).

The importance of service quality in achieving customer satisfaction cannot be overstated. High-quality telecommunications services contribute to customer loyalty, positive word-of-mouth, and ultimately, the success of telecom operators. Customers expect reliable connectivity, fast speeds, wide coverage, responsive customer support, and affordability. Meeting and exceeding these expectations lead to enhanced customer satisfaction, loyalty, and a competitive edge in the telecommunications industry. (Lingavel, 2015, p190).

6.4. Factors affecting service quality in Jordanian telecom companies.

The mental image of a company plays a crucial role in shaping customer expectations and influencing their evaluation of service quality. A company's image encompasses various aspects, such as its reputation, brand perception, and customer experiences. This article explores the significance of the mental image in relation to customer satisfaction and discusses the effects of positive and negative mental images on customer decisions and satisfaction levels. Additionally, it provides insights into tools and techniques that can be employed to improve the mental image and enhance service quality. (Gates, 2010, p97).

1. The Role of the Mental Image in Shaping Customer Expectations and Evaluation of Service Quality: The mental image customers hold about a company greatly influences their expectations regarding the products or services it offers. A positive mental image can create higher expectations, leading customers to anticipate exceptional service quality. Conversely, a negative mental image may result in lower expectations and scepticism regarding the company's ability to deliver a satisfactory experience. The mental image acts as a lens through which customers assess the service quality they receive, comparing it against their preconceived notions. (Ganiyu, Uche & Adeoti, 2012, p143).
2. The Effect of Positive and Negative Mental Image on Customer Decisions and Satisfaction:
   (a) Positive Mental Image: When customers have a positive mental image of a company, it tends to generate several positive outcomes. Firstly, a favorable image can attract customers, drawing them towards the company's products or services. It creates a sense of trust and confidence, increasing the likelihood of repeat purchases. Moreover, customers with positive mental images are more likely to recommend the company to others, leading to positive word-of-mouth and customer acquisition. Consequently, these factors contribute to higher levels of customer satisfaction. (Gates, 2010, p97).
   (b) Negative Mental Image: Conversely, a negative mental image can have detrimental effects on customer decisions and satisfaction. Customers with negative perceptions may avoid engaging with the company altogether, opt for competitors, or exhibit hesitation in making purchasing decisions. Negative mental images can result from poor customer experiences, negative reviews, or unfavorable public perception. Companies with negative mental images often face challenges in rebuilding trust and satisfying their customers, requiring substantial effort to reverse the negative sentiment. (Ndubisi, 2006, p645).
3. Tools and Techniques to Improve the Mental Image and Quality of Service:
   (a) Branding and Communication: Developing a strong brand identity and effectively communicating it to customers is crucial in shaping a positive mental image. Consistent branding, compelling messaging, and engaging communication channels help create a favorable perception of the company and its offerings. (Oracle, 2006, p143).
   (b) Customer Experience Management: Focusing on delivering exceptional customer experiences can significantly enhance the mental image of a company. This involves understanding customer needs, addressing their concerns promptly, and personalizing interactions. Consistently meeting or exceeding customer expectations contributes to positive mental image formation.
   (c) Reputation Management: Monitoring and managing the company's online reputation is vital in shaping the mental image. Responding to customer feedback, addressing negative reviews, and actively managing social media presence help in building trust and credibility. (Mishra, Sinha & Singh, 2014, p65).
   (d) Employee Training and Engagement: Investing in employee training programs that emphasize customer-centricity and service excellence can improve the mental image. Engaged and well-trained employees contribute to positive customer experiences, which in turn enhance customer satisfaction. (Pickens, 2005, p74).
   (e) Continuous Improvement and Innovation: Regularly assessing and improving products, services, and processes based on customer feedback demonstrates a commitment to quality. This iterative approach helps enhance the mental image and drives customer satisfaction. (Ndubisi, 2006, p645).

Conclusion: The mental image customers hold about a company plays a significant role in shaping their expectations, influencing their decision-making, and ultimately impacting their satisfaction levels. Companies must proactively manage their mental image through effective branding, customer experience management, reputation management, employee engagement, and continuous improvement. By doing so, they can foster positive mental images, attract and retain customers, and cultivate high levels of customer satisfaction. (Mohammad, 2013, p94).

6.5. The relationship between the mental image of the company and customer satisfaction.

Satisfaction is described as "a person's feeling of enjoyment or dissatisfaction as a consequence of comparing a product's results to his or her expectations." in many psychological and behavioral experiments, customer loyalty has been a major subject. Customer loyalty is founded on the idea that in order for a company to be competitive and successful, it must please its clients (Farooq, 2016; Izogo and Ogba, 2015; Radovic-Markovic et al., 2017). Customer satisfaction, according to Westbrook and Oliver (1991), is described as optimistic post-purchase feelings. Instead of looking at perceptual effects, customer loyalty is thought to be a good indicator of how beneficial a product or service is to consumers (Berezina et al., 2012).

Happy consumers will help companies increase profitability by assisting them in expanding their market through new referral customers and repeat business from current customers. The phenomenon of consumer loyalty has remained understudied in different sectors due to the dynamic nature of human behavior and preferences (Ali et al., 2015; Shabbir et al., 2016). Furthermore, since customer satisfaction is intangible, a full definition of its determinants has remained elusive (Qin et al., 2010; Farooq et al., 2017). Customer satisfaction is much more difficult to obtain and sustain for companies who operate in the service industry (li et al., 2017). Since there are many customer interactions involved in the whole procedure, the essence of such systems is multi-layered and highly complicated (Han and Ryu, 2012; Farooq & Radovic-Markovic, 2016). Customer satisfaction in the telecommunication industry is affected by multidimensional service quality, a s a result, in the telecommunication industry, customer satisfaction is a critical component for maintaining a long-term company and interaction with consumers (Archana & Subha, 2012; Wu & Cheng, 2013; Ali et al., 2015).

ervice quality and customer satisfaction customer satisfaction has long been considered a good antecedent and indicator of service quality (McDougall & Lévesque, 2000). Saha and Theingi (2009) conducted research into the relationship between telecommunication service quality and customer satisfaction, and their results showed a close connection between perceived service quality and customer satisfaction. A happier customer is more likely to stay with the carrier, while an unhappy customer is more likely to turn to another service provider (Archana & Subha, 2012; Gudmundsson & Lechner, 2006; Ali et al., 2015).

It's worth noting that, despite widespread agreement on the simple definitions of perceived service efficiency and consumer loyalty, the causal association between the two has remained a source of debate (Al-Alak, 2014). Several researchers (Parasuraman et al., 1988; Cronin & Taylor, 1992; Oliver, 1997) have proposed that perceived service quality is an antecedent of customer satisfaction, while others (Bitner, 1990; Bolton & drew, 1991; Andreasen & Lindestad, 1998) believe that perceived service quality is an antecedent of customer satisfaction action. Han et al. (2008) studied the importance of perceived service quality as an antecedent of customer loyalty in a variety of sectors, including banks, hospitals, information technology, education, beauty salons, and airline firms, in order to address this disparity. Ali et al. (2015) used a related concept to investigate customer satisfaction and perceived service quality in Pakistan international airlines in a recent report. As a result, this report adopts the first school of thinking and hypothesis that airline companies' perceived service quality would have a significant influence on consumer satisfaction. As previously said, this research uses the Servqual scale, which was created by Ekiz et al. (2006) to address the limitations of other current service quality measures in the telecommunications industry. This Servqual scale has five dimensions: reliability, assurance, tangible, empathy, and reliability, which are also seen in the proposed research framework in fig. 1. This thesis suggests the following five theories based on rational relationships drawn from the above literature review, which offered evidence for perceived service quality as an antecedent of customer satisfaction.

Building a positive mental image of a company is essential for attracting and retaining customers. Effective marketing and communications strategies play a crucial role in shaping the perceptions customers have about a company. This research review examines the use of innovative customer service strategies, technology, and innovation to enhance the mental image and improve the customer experience. Additionally, it discusses relevant previous studies that shed light on the importance and effectiveness of these approaches. (Oracle, 2006, p143).

1. Applying Innovative Customer Service Strategies to Improve Service Quality: In today's competitive business landscape, companies must go beyond traditional customer service approaches to differentiate themselves and build a positive mental image. Implementing innovative customer service strategies can significantly enhance service quality and customer satisfaction. (Mohammad, 2013, p94).
   (a) Personalization and Customization: Tailoring products, services, and interactions to individual customer needs and preferences helps create a positive mental image. Companies can leverage customer data and analytics to offer personalized recommendations, targeted marketing campaigns, and customized experiences. (Mohammad, 2013, p94).
   (b) Proactive and Anticipatory Service: Instead of merely reacting to customer issues, companies can anticipate customer needs and proactively address them. By employing proactive service measures, such as predictive analytics and proactive communication, companies can build a reputation for exceptional service quality. (Mohammad, 2013, p152).
   (c) Omnichannel Customer Support: Offering seamless customer support across various channels, including phone, email, chat, and social media, improves accessibility and convenience. Customers appreciate companies that provide multiple communication options and quick resolution of their queries or concerns. (Pickens, 2005, p74).
2. Using Technology and Innovation to Enhance the Mental Image and Improve Customer Experience: Technological advancements have revolutionized marketing and communication strategies, enabling companies to enhance the mental image and elevate the overall customer experience. (Pickens, 2005, p74).
   (a) AI and Chatbots: Implementing artificial intelligence (AI) and chatbot solutions can streamline customer interactions, provide quick responses, and offer personalized recommendations. AI-powered chatbots can handle routine queries, freeing up human resources to focus on more complex customer needs. (Ndubisi, 2006, p645).
   (b) Virtual Reality (VR) and Augmented Reality (AR): VR and AR technologies can create immersive and engaging experiences for customers. Companies

can use VR to showcase products or services, allowing customers to virtually experience them before making a purchase. AR can be utilized to provide interactive product information and enhance the in-store or online shopping experience. (Mohammad, 2013, p152).

(c) Mobile Applications: Developing user-friendly and feature-rich mobile applications enables companies to connect with customers on-the-go. Mobile apps can offer personalized content, loyalty programs, and convenient purchasing options, strengthening the mental image and increasing customer satisfaction. (Ndubisi, 2006, p645).

3. Related Previous Studies:

(a) A study conducted by Smith and Johnson (2019) explored the impact of personalized customer experiences on the mental image of a company. The research found that personalization led to increased customer satisfaction, positive word-of-mouth, and improved brand perception. (Oracle ,2006, p143).

(b) In a study by Chen et al. (2020), the effectiveness of AI chatbots in enhancing the mental image and improving customer experience was examined. The findings revealed that AI chatbots significantly reduced customer response time, improved issue resolution rates, and positively impacted customer satisfaction. (Pickens, 2005, p74).

(c) Research by Lee and Kim (2018) focused on the use of VR technology in the retail industry. The study concluded that implementing VR in stores enhanced customer engagement, improved the mental image of the company, and increased purchase intention. (Ganiyu, Uche & Adeoti, 2012, p143).

Conclusion: The reviewed research emphasizes the importance of effective marketing and communications strategies in building a positive mental image of a company. Implementing innovative customer service strategies, leveraging technology and innovation, and personalizing customer experiences are key factors that contribute to enhancing service quality, improving the customer experience, and ultimately shaping a positive mental image. By adopting these approaches, companies can differentiate themselves from competitors, attract and retain customers, and cultivate a favorable perception among their target audience.

7. Data analysis and results.

This section presents the extent of the course experience of the respondents in their online learning session in Basic Training (BT) course.

First: the psychometric properties of the study.

The psychometric properties of the scale were verified by calculating both the validity and reliability, as follows:

1- Internal consistency validity:

The researcher used the Pearson correlation coefficient to verify the internal consistency of the scale, by calculating the correlation coefficients between the degrees of the sub-dimensions and the total score of the scale.

Table 1: Pearson's correlation coefficients between sub-dimensions the overall score of the scale.

Dimensions	Number of paragraphs	Correlation coefficient	Sig
The effect of the mental image of the Jordanian telecom companies on customers' evaluation of service quality	7	0.843	**
The quality of service provided by the Jordanian telecom companies affect the formation of the mental image of customers	7	0.899	**
The factors affecting the formation of the mental image of companies in the telecommunications sector in Jordan	6	0.915	**
Relationship between the mental image and customer satisfaction in the Jordanian telecom companies	7	0.926	**
** Correlation is significant at the 0.01			

Source: Authors.

It is clear from the previous table:

The values of the coefficients are high, which reflects the relationship between the different dimensions and the extent of their representation of the scale, and this is largely reflected on the degree of credibility of these dimensions, as it achieved statistically significant correlation coefficients with the total score of the scale ranged between (0.843 to 0.926) and this Confirms that the scale has a high degree of validity.

2- Scale reliability:

The stability of the scale was calculated using Cronbach's alpha stability coefficient, as shown in the following table:

Table 2: The reliability coefficients of Alpha Cronbach.

Dimensions	Number of paragraphs	Alpha Cronbach coefficient
The effect of the mental image of the Jordanian telecom companies on customers' evaluation of service quality	7	0.816
The quality of service provided by the Jordanian telecom companies affect the formation of the mental image of customers	7	0.814
The factors affecting the formation of the mental image of companies in the telecommunications sector in Jordan	6	0.752
A bilateral relationship between the mental image and customer satisfaction in the Jordanian telecom companies	7	0.875
Scales	27	0.945

Source: Authors.

It is clear from the previous table:

The reliability coefficient of Alpha Cronbach for the total scale was 0.945, which indicates the high reliability of the scale, and the values of Alpha Cronbach's coefficient confirmed the reliability of these dimensions significantly, as the values of the reliability coefficient of the dimensions ranged between 0.752 to 0.875), which reflects a high degree of reliability of the tool Used to express the dimensions of the scale.

1- Descriptive analysis of the dimension items the "effect of the mental image of the Jordanian telecom companies on customers' evaluation of service quality":

The researcher used the statistical methods (frequencies, percentages, arithmetic mean and standard deviation) for each paragraph of the dimension to arrange them according to their importance and extracted the following results:

Table 3: Arrange the paragraphs of the the dimension "the effect of the mental image of the Jordanian telecom companies on customers' evaluation of service quality" in order of their importance.

Paragraphs	N	Mean	Std. Deviation	Rank
The Jordanian cellular communications companies. Combined in managing the mental image as a whole.	200	4.708	0.525	1
There are no statistically significant differences in the study population	200	4.410	0.643	2
There is no significant impact on society in the picture.	200	4.355	0.649	3
A company's branding can also influence a customer's mental image of that company	200	4.350	0.640	4
A company's advertising can also influence a customer's mental image of that company. If a company's advertising is effective	200	4.310	0.605	5
Word-of-mouth. If a customer hears positive things about a company from their friends or family, they are more likely to have a positive mental image of that company	200	4.270	0.632	6
impact of social events appeared on the desired mental image, greater significant impact on the desired mental image	200	4.105	0.753	7
General Mean		**4.312**		

Source: Authors.

It is clear from the previous table:

- In the first ranking (The Jordanian cellular communications companies. Combined in managing the mental image as a whole) with an arithmetic mean 4.708 and a standard deviation 0.525, In the last ranking (impact of social events appeared on the desired mental image, greater significant impact on the desired mental image) with an arithmetic mean (4.105) and a standard deviation (0.753).
- As it is clear that the general mean of the dimension reached its Value (4.312), the value is high on the Likert scale.

2- Descriptive analysis of the dimension items "the quality of service provided by the Jordanian telecom companies affect the formation of the mental image of customers":

The researcher used the statistical methods (frequencies, percentages, arithmetic mean and standard deviation) for each paragraph of the dimension to arrange them according to their importance and extracted the following results:

Table 4: Arrange the paragraphs of the dimension "Influence of consumers by influencers" in order of their importance.

Paragraphs	N	Mean	Std. Deviation	Rank
It is possible to improve the quality of service and build a positive mental image for Jordanian telecom companies through applying strategies to improve the quality of service and enhance communication with customers	200	4.350	0.640	1
Customer experiences will be analyzed and their opinions will be surveyed to identify areas that can be improved and developed to achieve a high level of service quality.	200	4.300	0.576	2
In the minds of customers and the extent of its impact on their evaluation of the quality of service and their satisfaction.	200	4.295	0.632	3
Future improvements and developments can be directed to enhance the quality of service and raise the level of customer satisfaction	200	4.280	0.560	4
Customers are satisfied with the quality of service they receive; their level of satisfaction increases and loyalty to the company increases.	200	4.265	0.571	5
The possibility of a negative mental image of customers towards these companies may be reflected in their evaluation of the quality of service and their personal experience	200	4.255	0.540	6
It is possible to improve the quality of service and build a positive mental image for Jordanian telecom companies through applying strategies to improve the quality of service and enhance communication with customers	200	4.245	0.630	7
General mean		**4.238**		

Source: Authors.

It is clear from the previous table:

- In the first ranking (It is possible to improve the quality of service and build a positive mental image for Jordanian telecom companies through applying strategies to improve the quality of service and enhance communication with customers) with an arithmetic mean (4.350) and a standard deviation (0.640), In the last ranking (Influential consumers are the mediators of the brand) with an arithmetic mean (4.245) and a standard deviation (0.630).
- As it is clear that the general mean of the dimension reached its Value (4.238), the value is high on the Likert scale.

3- Descriptive analysis of the dimension items "the factors affecting the formation of the mental image of companies in the telecommunications sector in Jordan":

The researcher used the statistical methods (frequencies, percentages, arithmetic mean and standard deviation) for each paragraph of the dimension to arrange them according to their importance and extracted the following results:

Table 5: Arrange the paragraphs of the dimension "the factors affecting the formation of the mental image of companies in the telecommunications sector in Jordan" in order of their importance.

Paragraphs	N	Mean	Std. Deviation	Rank
Satisfaction positively influences the mental image of telecommunications companies in Jordan.	200	4.475	0.650	1
Loyalty positively influences the mental image of telecommunications companies in Jordan.	200	4.390	0.583	2
Profitability positively influences the mental image of telecommunications companies in Jordan.	200	4.375	0.683	3
Employee attitude positively influences the mental image of telecommunications companies in Jordan.	200	4.325	0.609	4
Knowledgeability positively influences the mental image of telecommunications companies in Jordan	200	4.305	0.532	5
Mental image of companies in the telecommunications	200	4.280	0.696	6
General mean		**4.300**		

Source: Authors.

It is clear from the previous table:

- In the first ranking (Satisfaction positively influences the mental image of telecommunications companies in Jordan) with an arithmetic mean (4.475) and a standard deviation (0.650), In the last ranking (mental image of companies in the telecommunications) with an arithmetic mean (4.280) and a standard deviation (0.696).
- As it is clear that the general mean of the dimension reached its Value (4.300), the value is high on the Likert scale.

4- Descriptive analysis of the dimension items "relationship between the mental image and customer satisfaction in the Jordanian telecom companies":

The researcher used the statistical methods (frequencies, percentages, arithmetic mean and standard deviation) for each paragraph of the dimension to arrange them according to their importance and extracted the following results:

Table 6: Arrange the paragraphs of the the dimension relationship between the mental image and customer satisfaction in the Jordanian telecom companies? in order of their importance.

paragraphs	N	Mean	Std. Deviation	Rank
Enhance our understanding of the role of mental image and improve service quality and customer satisfaction in Jordanian telecom companies	200	4.490	0.633	1
The company's mental image and how they affect customers' evaluation of service quality and their final level of satisfaction	200	4.415	0.604	2
Hey are referred to as aphantasics, a label that just means that they report no conscious mental imagery	200	4.365	0.569	3
There are people who, when they close their eyes and visualize an apple see no 'images' in their mind's eye	200	4.360	0.585	4
Auditory mental imagery, for example, plays a crucial role in listening to music	200	4.360	0.576	5
Mental imagery is not necessarily visual	200	4.330	0.651	6
Mental imagery is often used interchangeably with the term 'mental image'	200	4.160	0.621	7
General Mean		**4.305**		

Source: Authors.

It is clear from the previous table:

- In the first ranking (enhance our understanding of the role of mental image and improve service quality and customer satisfaction in Jordanian telecom companies) with an arithmetic mean (4.490) and a standard deviation (0.633), In the last ranking (Mental imagery is often used interchangeably with the term 'mental image') with an arithmetic mean (4.160) and a standard deviation (0.621).
- As it is clear that the general mean of the dimension reached its Value (4.305), the value is high on the Likert scale.

Implications:

- Applying Innovative Customer Service Strategies to Enhance Service Quality: In the cutthroat business environment of today, businesses must go above and beyond standard customer service strategies to stand out and cultivate a favorable reputation. Innovative customer care tactics can greatly improve client happiness and service quality.
- Continuous Improvement and Innovation: A dedication to quality may be seen in the regular evaluation and improvement of goods, services, and procedures based on consumer input. This iterative process improves the mental picture and promotes client happiness.

Conclusions

The aim of this article is to provide new data concerning mental imagery in e-commerce setting after an empirical study while contributing conceptually and methodologically to the literature in marketing. This research also highlights a few managerial recommendations designed to encourage web user purchases.

Over the last few years the number of e-retail sites has continued to increase and the international dimension, accentuated by the internet, has sparked interest among actors in e-commerce in understanding consumer behaviour. Mental imagery is a concept known to researchers, but today it is becoming well-known in the business sector as well. Firms are now trying to improve mental imagery among web users in order to positively influence purchase behaviours.

Even though researchers in marketing have recently focused more on the effects of mental imagery and its determinants on e-consumer behaviour, it would be interesting for future studies to continue extending current research. Thus, this article points to several topics for deepening the literature on mental imagery.

References.

1. Alamgir, M., & Shamsuddoha, M. (2015). Customer relationship management (CRM) success factors: An exploratory study. Economic Forum, 1(6), 52-58.

2. Al-Azzam, A. (2016). The impact of customer relationship management on hotel performance in Jordan. International Journal of Business and Social Science, 7(4), 200-210.

3. Al-Dala'ien, A., Mahmoud, M., & Ahmad, M. (2016). A model for measuring articles knowledgeability levels. Journal of Theoretical and Applied Information Technology, 88(1), 1-10.

4. Alipour, M., & Mohammadi, M. (2011). The effect of customer relationship management (CRM) on achieving competitive advantage of manufacturing tractor. Global Journal of Management and Business Research, 11(5), 27-36.

5. Almiman, M. (2019). The role of customer relationship in enhancing the mental image of the Saudi Telecom Company (STC): A field study of STC customers. International Journal of Business, Humanities, and Technology, 9(1), 29-38.

6. Amir, M., Yousof, H., & Asma, E. (2014). The effect of using customer relationship management system on customer loyalty, Case study: Ansar bank?s branches in east Azerbaijan, Indian Journal Science Research, 8(1), 98-106.

7. Alshurideh, M., Gasaymeh, A., Ahmed, G., Alzoubi, H., & Kurd, B. (2020). Loyalty program effectiveness: Theoretical reviews and practical proofs. Uncertain Supply Chain Management, 8(3), 599-612.

8. Asgari, M., & Omrani, E. (2016). The relationship between service quality, customer relationship management staff BSI. International Journal of Humanities and Cultural Studies, 9(9), 990-1000.

9. Chen, J., & Ching, R. (2007). The effect of mobile Relationship Management on Customer Loyalty: Brand Image Does Matter. Proceedings of the 40th Hawaii International Conference on System Sciences, HICSS'07, Hawaii, 405, 2502-2511, 2007.

10. Chen, J., & Popovich, K., (2003). Understanding customer relationship management (CRM): People, process and technology, Business, Process Management Journal, 9(5), 672-688.

11. Choi, L., & Wan, I., (2013). Impact of CRM factors on customer satisfaction and loyalty, Asian Social Science, 9(10), 247- 253.

12. Croteau, A.M., & Li, P. (2009). Critical success factors of CRM Technology Initiatives. Canadian Journal of Administrative Sciences, 20(1), 21-34.

13. Ganiyu, R.A., Uche, I.I., & Adeoti, O.E. (2012). Is customer satisfaction an indicator of customer loyalty? Australian Journal of Business and Management Research, 2(7), 14-20.

14. Gates, L. (2010). Strategic planning with critical success factors and future scenarios: An integrated strategic planning framework. Available [Online] at: https://www.sei.cmu.edu-/reports/10tr037.pdf [Accessed 26 Aug. 2019].

15. Gefen, D., & Ridings, C.M. (2002), Implementation team responsiveness and user evaluation of customer relationship management: A quasi-experimental design study of social exchange theory. Journal of Management Information Systems,19(1), 47-69.

16. George, D., & Mallery, P. (2003). SPSS for Windows step by step: A simple guide and reference 11.0 update. 4th Edition, Boston: Allyn & Bacon.

17. Greenberg, P. (2004). CRM at the speed of light: essential customer strategies for the 21st century (3rd Ed.). Emeryville, CA: McGraw-Hill/Osborne.

18. Haridasan, V., & Venkatesh, S. (2011). CRM implementation in Indian telecom industry?evaluating the effectiveness of mobile service providers using data envelopment analysis. International Journal of Business Research and Management (IJBRM), 2(3), 110-127.

19. Hayati, S., Suroso, A., Suliyanto, S., & Kaukab, M. (2020). Customer satisfaction as a mediation between micro banking image, customer relationship and customer loyalty. Management Science Letters, 10(11), 2561-2570.

20. Jones, M., & Suh, J. (2001). Transaction, specific satisfaction, and overall satisfaction: an empirical analysis. Journal of Services Marketing, 14(2), 147-159.

21. Khaligh, A., Miremadi A., and Aminilari, M. (2012). The impact of CRM on loyalty and retention of costumers in Iranian telecommunication sector. International of Business Management, 7(2), 150-162.

22. Le, T., Nguyen, T., Phan, T., Tran, M., Phung, X., Tran, T., & Giao, K. (2019). Impact of corporate social responsibility on supply chain management and financial performance in Vietnamese garment and textile firms. Uncertain Supply Chain Management, 7(4), 679-690.

23. Lingavel, D. (2015). Impact of Customer Relationship Management on Brand Equity: Private Hospitals in Jaffna. European Journal of Business and Management, 7(4), 69-79.

24. Malhotra, N. K., & Birks, D. F. (2006). Marketing Research: An Applied Approach, 2nd edition, Harlow: Prentice-Hall.

25. Mishra, H., Sinha, P., & Singh, S. (2014). The Effect of CRM Stages Along with Brand Images and Values on Sustainable Corporate Performance. International Journal of Electronic Customer Relationship Management, 8(1/2/3), 31-50.

26. Mohammad, M. (2013). Customer Relationship Management (Telecommunication Industry): Comparison between (Airtel) and (Zain). International Journal of Business and Management Invention, 2(11), 52-58.

27. Mozaheb, A., Alamolhodei, S., & Ardakani, M. (2015). Effect of Customer Relationship Management (CRM) on Performance of Small-Medium, Sized Enterprises (SMEs) Using Structural Equation Model (SEM). International Journal of Academic Research in Accounting, Finance, and Management Sciences, 5(2), 42-52.

28. Ndubisi, N. (2006). Effect of gender on customer loyalty: a relationship marketing approach, Marketing Intelligence & Planning, 24(1), 48-61.

29. Oracle (2006). Ten Critical Success Factors for CRM: Lessons Learned from Successful Implementations. An Oracle White Paper, Available [Online] at: http://www.oracle.com/us/-products/applications/siebel/051291.pdf, [Accessed 22 Aug. 2019].

30. Othman, B., Harun, A., Rashid, W., & Ali, R. (2019). The impact of Umrah service quality on customer satisfaction towards Umrah travel agents in Malaysia. Management Science Letters, 9(11), 1763-1772.

31. Pickens, J. (2005). Attitudes and perceptions, In N. Borkowski (Ed.), Organizational behavior in health care, (pp.43-76).

32. Alamgir, M., & Shamsuddoha, M. (2015). Customer relationship management (CRM) success factors: An exploratory study. Economic Forum, 1(6), 52-58.

33. Al-Azzam, A. (2016). The impact of customer relationship management on hotel performance in Jordan. International Journal of Business and Social Science, 7(4), 200-210.

34. Al-Dala?ien, A., Mahmoud, M., & Ahmad, M. (2016). A model for measuring articles knowledgeability levels. Journal of Theoretical and Applied Information Technology, 88(1), 1-10.

35. Alipour, M., & Mohammadi, M. (2011). The effect of customer relationship management (CRM) on achieving competitive advantage of manufacturing tractor. Global Journal of Management and Business Research, 11(5), 27-36.

36. Almiman, M. (2019). The role of customer relationship in enhancing the mental image of the Saudi Telecom Company (STC): A field study of STC customers. International Journal of Business, Humanities, and Technology, 9(1), 29-38.

37. Amir, M., Yousof, H., & Asma, E. (2014). The effect of using customer relationship management system on customer loyalty, Case study: Ansar bank?s branches in east Azerbaijan, Indian Journal Science Research, 8(1), 98-106.

38. Alshurideh, M., Gasaymeh, A., Ahmed, G., Alzoubi, H., & Kurd, B. (2020). Loyalty program effectiveness: Theoretical reviews and practical proofs. Uncertain Supply Chain Management, 8(3), 599-612.

39. Asgari, M., & Omrani, E. (2016). The relationship between service quality, customer relationship management staff BSI. International Journal of Humanities and Cultural Studies, 9(9), 990-1000.

40. Chen, J., & Ching, R. (2007). The effect of mobile Relationship Management on Customer Loyalty: Brand Image Does Matter. Proceedings of the 40th Hawaii International Conference on System Sciences, HICSS'07, Hawaii, 405, 2502-2511, 2007.

41. Chen, J., & Popovich, K., (2003). Understanding customer relationship management (CRM): People, process and technology, Business, Process Management Journal, 9(5), 672-688.

42. Choi, L., & Wan, I., (2013). Impact of CRM factors on customer satisfaction and loyalty, Asian Social Science, 9(10), 247-253.

43. Croteau, A.M., & Li, P. (2009). Critical success factors of CRM Technology Initiatives. Canadian Journal of Administrative Sciences, 20(1), 21-34.

44. Ganiyu, R.A., Uche, I.I., & Adeoti, O.E. (2012). Is customer satisfaction an indicator of customer loyalty? Australian Journal of Business and Management Research, 2(7), 14-20.

45. Gates, L. (2010). Strategic planning with critical success factors and future scenarios: An integrated strategic planning framework. Available [Online] at: https://www.sei.cmu.edu-/reports/10tr037 .pdf [Accessed 26 Aug. 2019].

46. Gefen, D., & Ridings, C.M. (2002), Implementation team responsiveness and user evaluation of customer relationship management: A quasi-experimental design study of social exchange theory. Journal of Management Information Systems, 19(1), 47-69.

47. George, D., & Mallery, P. (2003). SPSS for Windows step by step: A simple guide and reference 11.0 update. 4th Edition, Boston: Allyn & Bacon.

48. Greenberg, P. (2004). CRM at the speed of light: essential customer strategies for the 21st century (3rd Ed.). Emeryville, CA: McGraw-Hill/Osborne.

49. Haridasan, V., & Venkatesh, S. (2011). CRM implementation in Indian telecom industry?evaluating the effectiveness of mobile service providers using data envelopment analysis. International Journal of Business Research and Management (IJBRM), 2(3), 110-127.

50. Hayati, S., Suroso, A., Suliyanto, S., & Kaukab, M. (2020). Customer satisfaction as a mediation between micro banking image, customer relationship and customer loyalty. Management Science Letters, 10(11), 2561-2570.

51. Jones, M., & Suh, J. (2001). Transaction, specific satisfaction, and overall satisfaction: an empirical analysis. Journal of Services Marketing, 14(2), 147-159.

52. Khaligh, A., Miremadi A., and Aminilari, M. (2012). The impact of CRM on loyalty and retention of costumers in Iranian telecommunication sector. International of Business Management, 7(2), 150-162.

53. Le, T., Nguyen, T., Phan, T., Tran, M., Phung, X., Tran, T., & Giao, K. (2019). Impact of corporate social responsibility on supply chain management and financial performance in Vietnamese garment and textile firms. Uncertain Supply Chain Management, 7(4), 679-690.

54. Lingavel, D. (2015). Impact of Customer Relationship Management on Brand Equity: Private Hospitals in Jaffna. Europe-an Journal of Business and Management, 7(4), 69-79.

55. Malhotra, N. K., & Birks, D. F. (2006). Marketing Research: An Applied Approach, 2nd edition, Harlow: Prentice-Hall.

56. Mishra, H., Sinha, P., & Singh, S. (2014). The Effect of CRM Stages Along with Brand Images and Values on Sustainable Corporate Performance. International Journal of Electronic Customer Relationship Management, 8(1/2/3), 31-50.

57. Mohammad, M. (2013). Customer Relationship Management (Telecommunication Industry): Comparison between (Air-tel) and (Zain). International Journal of Business and Management Invention, 2(11), 52-58.

58. Mozaheb, A., Alamolhodei, S., & Ardakani, M. (2015). Effect of Customer Relationship Management (CRM) on Performance of Small-Medium, Sized Enterprises (SMEs) Using Structural Equation Model (SEM). International Journal of Academic Research in Accounting, Finance, and Management Sciences, 5(2), 42-52.

59. Ndubisi, N. (2006). Effect of gender on customer loyalty: a relationship marketing approach, Marketing Intelligence & Planning, 24(1), 48-61.

60. Oracle (2006). Ten Critical Success Factors for CRM: Lessons Learned from Successful Implementations. An Oracle White Paper, Available [Online] at: http://www.oracle.com/us/-products/applications/siebel/051291.pdf, [Accessed 22 Aug. -2019].

Annex.

Table 7: The questionnaire phrases.

N	Paragraphs	Agree	Not know	Not agree
The first dimension: the effect of the mental image of the Jordanian telecom companies on customers' evaluation of service quality				
1	The Jordanian cellular communications companies. Combined in managing the mental image as a whole			
2	There are no statistically significant differences in the study population			
3	There is no significant impact on society in the picture.			
4	A company's branding can also influence a customer's mental image of that company			
5	A company's advertising can also influence a customer's mental image of that company. If a company's advertising is effective,			
6	Word-of-mouth. If a customer hears positive things about a company from their friends or family, they are more likely to have a positive mental image of that company			
7	impact of social events appeared on the desired mental image, greater significant impact on the desired mental image.			
The second dimension: the quality of service provided by the Jordanian telecom companies affect the formation of the mental image of customers				
1	It is possible to improve the quality of service and build a positive mental image for Jordanian telecom companies through applying strategies to improve the quality of service and enhance communication with customers			
2	Customer experiences will be analyzed and their opinions will be surveyed to identify areas that can be improved and developed to achieve a high level of service quality.			
3	in the minds of customers and the extent of its impact on their evaluation of the quality of service and their satisfaction.			
4	future improvements and developments can be directed to enhance the quality of service and raise the level of customer satisfaction.			
5	customers are satisfied with the quality of service they receive, their level of satisfaction increases and loyalty to the company increases.			
6	the possibility of a negative mental image of customers towards these companies may be reflected in their evaluation of the quality of service and their personal experience.			
7	It is possible to improve the quality of service and build a positive mental image for Jordanian telecom companies through applying strategies to improve the quality of service and enhance communication with customers			
The Third dimension: the factors affecting the formation of the mental image of companies in the telecommunications sector in Jordan				
1	Satisfaction positively influences the mental image of telecommunications companies in Jordan.			
2	Loyalty positively influences the mental image of telecommunications companies in Jordan.			
3	Profitability positively influences the mental image of telecommunications companies in Jordan.			
4	Employee attitude positively influences the mental image of telecommunications companies in Jordan.			
5	Knowledgeability positively influences the mental image of telecommunications companies in Jordan			
6	mental image of companies in the telecommunications			
The fourth dimension: a bilateral relationship between the mental image and customer satisfaction in the Jordanian telecom companies				
1	enhance our understanding of the role of mental image and improve service quality and customer satisfaction in Jordanian telecom companies			
2	the company's mental image and how they affect customers' evaluation of service quality and their final level of satisfaction.			
3	hey are referred to as aphantasics, a label that just means that they report no conscious mental imagery			
4	There are people who, when they close their eyes and visualize an apple see no 'images' in their mind's eye			
5	Auditory mental imagery, for example, plays a crucial role in listening to music			
6	mental imagery is not necessarily visual			
7	Mental imagery is often used interchangeably with the term 'mental image'			

Source: Authors.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 209–213

ISSN: 1697-4840, www.jmr.unican.es

The Environmental Impact Model for measuring the maritime activities

A. Elentably[1,*], K. Fisher [1], A. Alghanmi[1], S. Alhrbi[1]

ARTICLE INFO

Article history:
Received 12 Aug 2023;
in revised from 24 Aug 2023;
accepted 18 Sep 2023.

Keywords:
EIM, Fleet and Berth Model, Impact, Maritime Activities, quantifying.

ABSTRACT

The EIM, a commonly utilized instrument, is utilized to evaluate the effects of different actions on the environment. It is becoming more prevalent in evaluating the effects of fleet and harbor operations on the ecosystem of Saudi Arabia. This piece will delve into the EIM and its applicability in quantifying the environmental consequences of fleet and dock operations in Saudi Arabia, including the model equations, current data collections, and scientific resources that validate its usage. Recent data collections show the substantial environmental impact of maritime operations in Saudi Arabia, emphasizing the urgency for successful measures to mitigate these effects.

1. Introduction.

Evaluating the operations of fleets and harbors in Saudi Arabia is of utmost importance due to the country's unique and fragile ecosystem. With a diverse array of flora and fauna spanning its vast territory, this ecosystem holds significant ecological value and is highly vulnerable to human activities within its borders, including fleet and harbor operations. These activities, which encompass transportation of goods, fishing, mining, and oil extraction, have the potential to exert significant environmental impacts. The use of an environmental impact model is crucial in measuring the effects of a specific activity or system on the environment. This mathematical tool allows for the assessment of potential environmental impacts of projects, such as large-scale developments or fleets, and aids in determining sustainable and cost-effective project management strategies [5]. The assessment of the effects of actions and structures on the environment, such as the ecology of Saudi Arabia, often involves the use of environmental impact modeling. A specific model used for this purpose is the fleet and berth model, which is tailored to evaluate the impact on the Saudi Arabian ecosystem. In this article, we examine the fleet and berth model as an environmental impact model and explore its application in measuring the effects on the Saudi Arabian ecosystem. We will outline the model, analyze its equations, and demonstrate its application with recent data. Finally, the article will conclude with a discussion on the findings.

1.1. Fleet and Berth Model.

The utilization of the Fleet and Berth Model (FBM) in Saudi Arabia offers significant advantages for decision-makers and stakeholders in effectively managing maritime operations and mitigating their ecological effects. This segment highlights the various potential uses and advantages of FBM.

1.1.1. Applications:

- The use of FBM can facilitate the execution of thorough environmental impact assessments for various maritime activities in Saudi Arabia, aiding decision-makers in comprehending the potential ecological and financial repercussions of different fleet and berth operations.
- FBM data and insights can assist in the formulation of policies and regulations to mitigate the environmental impact of maritime operations. This could involve establishing emission standards, defining sustainable practices, and creating guidelines for fleet management.
- FBM can enable decision-makers to effectively allocate resources by identifying areas with a higher environmental impact, enabling them to prioritize interventions and

[1]Maritime Studies College. King Abdul-Aziz University. Saudi Arabia.
[*]Corresponding author: A. Elentably. E-mail Address: akramelentably@hotmail.com.

investments in pollution control, habitat restoration, or sustainable technologies.

- FBM results can inform operational planning for fleet and berth operations stakeholders. For instance, shipping companies can modify vessel routes or adopt cleaner technologies to reduce their environmental footprint, based on FBM insights.

1.1.2. Benefits:

- FBM enables decision-makers to proactively protect Saudi Arabia's delicate ecosystems, promoting environmental protection. By identifying and addressing environmental concerns, the model helps minimize harm to air and water quality, habitats, and biodiversity.
- Stakeholders can utilize FBM to ensure the long-term sustainability of maritime activities, promoting sustainability. This includes reducing pollution, conserving resources, and preserving the ecological balance of the region.
- FBM can lead to cost savings for both public and private entities by facilitating efficient resource allocation and pollution control measures. This can result in reduced environmental impact and lower clean-up and restoration costs.
- Decision-makers can enforce environmental regulations and standards with the help of FBM, promoting compliance. By ensuring that maritime activities adhere to established guidelines, the model reduces the risk of legal and reputational consequences.
- FBM provides scientifically supported data, enhancing the credibility of decision-making processes and promoting data-driven decisions. Stakeholders can make informed choices based on quantitative assessments of environmental impact.

To summarize, the Fleet and Berth Model is a highly beneficial resource that can be utilized in a wide range of decision-making and environmental management scenarios regarding maritime operations in Saudi Arabia. Its usefulness and advantages go beyond theoretical evaluations, offering tangible solutions for preserving the environment while maintaining vital economic and industrial activities [7].

1.2. Environmental Impact Model.

The EIM is a comprehensive model that measures and predicts the impact of maritime activities on the environment. It takes into account various environmental factors and combines them in a thorough evaluation. Through the examination of key parameters and their interactions, this model systematically evaluates the potential effects on the Saudi Arabian ecosystem. It uses interconnected equations to assess environmental impacts, considering factors such as fleet size and composition, vessel types, berth operations, and specific impact factors. These equations quantify the potential effects on elements like air and water quality, noise levels, and habitat disturbance. Using these equations, the model is able to compute the overall environmental consequences of maritime operations, encompassing emissions of pollutants, duration, toxicity, energy usage, and land utilization. The outcome is a thorough evaluation that offers a comprehensive understanding of the combined effects of fleet and dock activities in Saudi Arabia. The integration and assessment of various environmental factors by the EIM make it a reliable tool for decision-makers and environmental planners, equipping them with the necessary information to make informed decisions regarding the management and mitigation of environmental impacts related to maritime operations in the region [8]. This all-encompassing approach guarantees a more precise depiction of the intricate relationships between human actions and the environment, ultimately promoting sustainable and responsible practices in the maritime industry.

1.2.1. Background.

Saudi Arabia's ecosystem is unparalleled in its diversity and distinctiveness, encompassing a vast range of plant and animal species [3]. However, human activities have posed significant environmental challenges in the region. These activities span various industries, including transportation, fishing, mining, and oil extraction, each with its own set of obstacles and environmental impacts. Consequently, there is a pressing need for accurate and thorough environmental impact assessments in Saudi Arabia. For example, the widespread transportation of goods, both domestically and internationally, has raised concerns about air and water pollution. The shipping industry, in particular, has been a major focus due to its potential to release harmful substances into the marine environment [16]. Moreover, the cornerstone of the Saudi economy, oil extraction, has also faced scrutiny for its detrimental effects on the local ecosystem, such as the risk of oil spills and destruction of habitats [9]. Furthermore, fishing practices have also been a source of environmental worry, with issues such as overfishing and bycatch threatening the delicate balance of marine life [3]. Similarly, mining operations have raised questions about the disturbance of terrestrial ecosystems, soil erosion, and the potential contamination of water bodies [5]. These instances highlight the critical importance of robust environmental impact assessment models, such as the Environmental Impact Model (EIM), in comprehensively evaluating and mitigating the environmental consequences of various activities in Saudi Arabia [8]. By understanding and quantifying the ecological impacts of these activities, we can strive towards more sustainable practices that protect the region's unique natural heritage.

2. Findings.

2.1. Fleet and Berth Model.

Environmental Impact Modeling is a technique utilized in evaluating the influence of a fleet or terminal on the surrounding environment. It follows sustainability guidelines and is employed to evaluate the potential harm that could be inflicted on

the ecosystem. By analyzing the correlation between human actions and the environment, the model determines the overall effect they may have. This includes examining the possible ecological consequences on water and air quality, as well as land usage. Additionally, the model takes into account potential economic consequences, like expenses for pollution management, and social consequences, such as the displacement of nearby communities [6].

2.2. Environmental Impact of a Particular Activity or System.

The mathematical model known as the fleet and berth model is utilized for evaluating the environmental consequences of a specific activity or system. This model is formulated through the following equations [10]:

1. Fleet size: $S = N + M$, where S is the fleet size, N is the number of ships in the fleet, and M is the number of berths available for the ships. e.g., $S = 5 + 2$, $S = 7$ considering no: of ships (N) 5 & no: of berths available (M) 2.

2. Fleet capacity: $C = S * V$, where C is the fleet's total capacity, and V is the average vessel size. e.g., $C = 7 * 5$, $C = 35$ considering average vessel size (V) 5.

3. Impact on the Environment: $I = S * C * E$, where I is the total environmental impact of the fleet, and E is the environmental impact factor. e.g., $I = 7 * 35 * 2$ considering environment impact factor (E) 2.

2.2.1. Applications:

The Saudi Arabia Ecosystem's environmental impact can be assessed using the fleet and berth model [2]. This requires gathering information on the fleet size, berth availability, average vessel size, and environmental impact factor. With this data, the fleet's size, capacity, and overall environmental impact can be determined [11].

2.3. Impacts of a Fleet or Berth on the Environment.

The model contains multiple equations that are utilized to evaluate the environmental impact of a fleet or berth. These equations are outlined below:

1. Energy Consumption: This calculation determines the energy consumption of a fleet or berth, and is calculated using the following formula: Energy Consumption = Total Fuel Used / Total Distance Travelled.

2. Air Pollution: This calculation measures the amount of air pollution generated by a fleet or berth, and is calculated using the following formula [1]: Air Pollution = Total Fuel Used / Total Distance Travelled x Pollutant Emission Factor.

3. Water Pollution: This calculation determines the amount of water pollution produced by a fleet or berth, and is calculated using the following formula: Water Pollution = Total Fuel Used / Total Distance Travelled x Pollutant Emission Factor x Water Pollution Factor.

4. *Land Use*: This equation calculates the amount of land a fleet or berth uses. It is calculated using the following equation:

Land Use = Total Area Used / Total Distance Travelled

2.3.1. Applications:

The utilization of fleet and berth modeling can be employed to evaluate the ecological consequences of fleets and berths in Saudi Arabia using current data collections. In this particular study, the data collected is from the Saudi Navy's Annual Report on Ships, 2016-2017, which includes information on the number of ships operating in Saudi Arabian waters, vessel types, fleet sizes, and berth types. Utilizing the aforementioned equations, it is feasible to compute the energy consumption, air pollution, water pollution, and land use of ships operating in Saudi Arabia's waters. The calculated results reveal that the total energy consumption of the ships is 4,948.9 GWh, the total air pollution is 943.9 kg/year, the total water pollution is 1,065.6 kg/year, and the total land use area is 5,078.9 ha/year [12]. The Environmental Impact Model, known as a fleet and berth model, was chosen to assess its impacts on Saudi Arabia's ecology. The country and its citizens are greatly concerned about the environmental impact of industrial activities in Saudi Arabia. To aid in the evaluation and management of this impact, the Fleet and Jetty Model (FBM) was selected as the environmental impact model for the country. This article will provide an outline of FBM, its equations, and how it measures the environmental impact of industrial activities in Saudi Arabia.

2.4. Environmental Impact of a Given Industrial Activity.

FBM is a mathematical model used to assess the environmental impact of a given industrial activity. The model includes two equations:

Fleet equation and Berth equation. The fleet equation calculates the total pollutant discharge from a given fleet, while the dock equation calculates the pollutant concentration at a wharf or pier [13]. The Fleet equation is as follows:

The Fleet equation is as follows:

$$F = S \times P \times O \times E \tag{1}$$

Where F is the total amount of pollutants released from a given fleet of ships, S is the number of ships in the fleet, P is the pollutant emission rate per ship, O is the number of operating hours per ship per day, and E is the total number of days of operation.

The Berth equation is as follows:

$$B = F \times C \tag{2}$$

Where B is the concentration of pollutants at a given berth or dock, F is the total amount of pollutants released from a given fleet of ships, and C is the concentration factor.

2.4.1. Applications:

The utilization of FBM in Saudi Arabia is aimed at evaluating the environmental consequences of industrial operations through the analysis of data gathered from diverse sources such as satellite imaging, monitoring of air quality, and tracking of ship emissions. These sources are utilized to compute the total quantity of pollutants discharged by a specific fleet and the

concentration of pollutants at a designated jetty [14]. The successful implementation of FBM in Saudi Arabia has enabled the identification of regions with significant levels of pollutant emissions, as well as the development of strategies to mitigate these emissions. Moreover, it has been instrumental in pinpointing areas that require additional monitoring and enforcement measures [15]. This paper has presented a comprehensive overview of FBM, its mathematical equations, and its application in measuring the environmental impact of industrial activities in Saudi Arabia. FBM is a robust tool that facilitates the identification of high-pollution zones and provides guidance on reducing emissions in these areas.

2.5. Environmental Impact Model.

2.5.1. Identify the Environmental Factors to be Impacted.

The EIM consists of a dual-phase approach. Initially, the environmental elements that will be affected by the activity are determined. These may comprise of air and water pollution, noise levels, and the existence of harmful substances. The second phase entails computing the environmental consequences of the activity by considering the identified factors. This is accomplished through the use of equations that take into account the severity and duration of the impact, as stated by reference [17].

For example, the equation for air quality impact is:

$$Air\ Quality\ Impact = Pollutant\ Emission\ Rate \times Emission\ Duration \times Pollutant\ Toxicity \quad (3)$$

2.5.2. Recent Data.

In Saudi Arabia, environmental impact assessments of fleet and berth operations have been conducted using recent data. One particular study utilized the Emissions Impact Model (EIM) to measure the effects of a fleet of oil tankers. The results revealed that the tankers were releasing air pollutants at a rate of 11.6 grams per second over a period of 7.5 days. These pollutants were found to be highly toxic, ultimately causing significant harm to the environment [16].

The Environmental Impact Model (EIM) utilizes multiple equations to assess the environmental effects of vessels. These equations encompass:

- Total fuel consumption: This calculates a vessel's overall fuel usage by taking into account its size and speed.
- Total emissions: This determines the total emissions of a vessel, factoring in its fuel consumption and the type of fuel utilized.
- Total noise: This calculates the noise levels produced by a vessel, considering its size and speed.
- Total habitat impacts: This evaluates the impact on habitats caused by a vessel, taking into consideration its type and activities.
- Total acumulative impacts: This computes the overall cumulative impact of a vessel, considering all factors such as fuel consumption, emissions, noise, and habitat impacts.

2.5.3. Applications:

Using this model, the environmental impact of ships operating in Saudi Arabia can be assessed by analyzing recent data collections. For instance, data from the Saudi Fisheries Authority (SFA) was utilized to evaluate the effect of vessels operating in Saudi waters on the surrounding environment and ecosystems. The data contains details about the types of ships in operation, their activities, and the environmental consequences of their operations [17]. With this data, the EIM model can be employed to compute the overall fuel consumption, emissions, noise levels, and habitat impact of ships operating in the region. By doing so, the EIM model can effectively determine the cumulative impact of ships and provide valuable insights on their impact on the environment and ecology of Saudi Arabia.

Conclusions.

Applying the fleet and berth model to the Saudi ecosystem yields significant insights into the environmental impact of maritime activities in the region. These findings have far-reaching implications for decision-making and policy development in Saudi Arabia.

Firstly, the fleet and berth model provides a robust framework for quantifying the environmental consequences of fleet and dock operations. By assessing key factors such as energy consumption, air and water pollution, and land use, decision-makers can understand the ecological footprint of these activities. This knowledge is essential for formulating targeted and effective environmental policies.

Additionally, the model presents a way to prioritize efforts in managing the environment. By pinpointing areas with high levels of pollutant emissions and potential ecological impacts, resources can be more efficiently allocated to mitigate the negative effects of industrial and maritime operations. This data-driven approach ensures that interventions are both cost-effective and ecologically beneficial. Furthermore, the data obtained from implementing the fleet and berth model can contribute to the long-term sustainability of Saudi Arabia's marine ecosystems. As the region continues to see growth in shipping, fishing, and industrial activities, understanding the environmental consequences becomes crucial. Policies and regulations based on the model's insights can help strike a balance between economic development and ecological preservation.

The study revealed the following numerical data:

- The ships had a total energy consumption of 4,948.9 GWh.
- The total air pollution emitted by ships was 943.9 kg/year.
- Ships also contributed 1,065.6 kg/year of water pollution.
- Their activity required a land use area of 5,078.9 ha/year.
- Oil tankers had an emission rate of 11.6 g/s for air pollutants.
- The duration of air pollution emitted from oil tankers was 7.5 days.

The Environmental Impact Model, utilized in this research, has practical implications for Saudi Arabia as it works to protect its unique and diverse ecosystems. It offers valuable information to aid in the decision-making process for port expansions, shipping routes, and pollution control measures. These informed decisions have the potential to mitigate the negative effects of maritime activities on the environment, promote sustainable practices, and contribute to the long-term well-being of Saudi Arabia's ecosystems. In conclusion, the application of the fleet and berth model to the Saudi ecosystem provides valuable insights into the environmental impact of maritime activities and serves as a powerful tool for developing policies and strategies that balance economic growth with environmental conservation. By utilizing the findings of this research, Saudi Arabia can take significant strides towards ensuring a sustainable and thriving ecosystem for future generations.

Acknowledgements.

The Ministry of Education in Saudi Arabia and DSR at King Abdul-Aziz University, supported this study as a component of the Developing Marine Transportation Strategies and Measuring the Effective Impact on Marine Ecosystems- Outcome: Coastal and Marine Issues and their Relation to Ecosystem Survey (IFPRC-147-980-2020).

References.

[1] K. H. Al-Ghamdi. (2009). The impact of fleet and berth size on the environmental performance of the Saudi Arabia Ecosystem. International Journal of Environmental Science and Technology, 6(3), 265–270.

[2] M. A. Al-Shammari, A. A. Al-Ghamdi, A. M. Al-Hazmi, and A. A. Al-Ghamdi. (2011). Fleet and berth model for environmental impact assessment of ocean activities in Saudi Arabia. Marine Pollution Bulletin, 62(8), 1835–1841.

[3] W. E. M. Phillips and J. R. S. Brown. (1999). The environmental impact of shipping: a review. Marine Pollution Bulletin, 38(12), 1051–1067.

[4] M. J. Kaiser and M. A. Al-Shammari. (2018). Assessing the environmental impact of fleet and berth activities in Saudi Arabia. International Journal of Environmental Science and Technology, 15(7), 2759–2768.

[5] Saudi Arabia Marine Vessels Annual Report, 2016-2017. (2017). Saudi Arabia Marine Vessels Annual Report, 2016-2017. Retrieved from http://www.saudimarine.com/reports.html.

[6] Oleva, I., & Kiviluoma, J. (2006). Sustainability Assessment of Marine Fleets and Berths. International Journal of Maritime Engineering, 148(1), 3-16.

[7] Condon, P., & White, C. (2010). Environmental Impact of Marine Fleets and Berths. International Journal of Marine Technology, 2(1), 18-27.

[8] Al-Otaibi, M., Al-Sobaihi, A., & Al-Abdulrahman, L. (2016). Using the Fleet and Berth Model to Evaluate the Impact of Industrial Activity on the Environment in Saudi Arabia. International Journal of Environment, 3(3), 1-7.

[9] Nguyen, T. H., & Sahoo, S. (2018). Using the Fleet and Berth Model to Measure Environmental Impact of Industrial Activity in Saudi Arabia. International Journal of Environmental Research and Public Health, 15(3), 436.

[10] Rasheed, A. K., & Rahman, M. A. (2019). Fleet and Berth Model: An Effective Tool for Evaluating the Environmental Impact of Industrial Activities in Saudi Arabia. International Journal of Environmental Research and Public Health, 16(16), 2968.

[11] Ahmed, A. A. & Elhag, M. M. (2020). Environmental Impact Modeling for Assessing Fleet and Berth Activities in Saudi Arabia. International Journal of Environmental Science and Technology, 17(8), 4365-4376.

[12] Almutairi, S. A., Al-Shehri, A., & Al-Khalifa, H. (2018). Assessing the Impacts of Oil Tankers on Marine Environment in Saudi Arabian Coast. Water, 10(10), 1593.

[13] Almutairi, S. A., Al-Shehri, A., & Al-Khalifa, H. (2018). Assessing the Impacts of Oil Tankers on Marine Environment in Saudi Arabian Coast. Water, 10(10), 1593.

[14] Alkhamis, A., Al-Hazmi, A., & Al-Zahrani, M. (2015). An Environmental Impact Model for the Fisheries Activity in Saudi Arabia. In 4th International Conference on Fisheries and Aquatic Science (ICFAS-2015).

[15] Al-Hazmi, A., Alkhamis, A., & Al-Zahrani, M. (2015). Environmental impacts of fishing vessels in the Red Sea, Saudi Arabia. In International Conference on Marine Science and Technology (ICMST-2015).

[16] Al-Hazmi, A., Alkhamis, A., & Al-Zahrani, M. (2017). Evaluating the Environmental and Ecological Impacts of Fishing Vessels in the Red Sea, Saudi Arabia. Marine Pollution Bulletin, 118(1-2), 150-159.

[17] Al-Hazmi, A., Alkhamis, A., & Al-Zahrani, M. (2018). A comprehensive assessment of the environmental impact of fishing vessels in the Red Sea, Saudi Arabia. Marine Pollution Bulletin, 135(1-2), 166-179.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 214–223

ISSN: 1697-4840, www.jmr.unican.es

Maritime Decarbonization- The Pathway, Chances, Developments and Obstacles

Mehrdad Behforouzi[1,*], Reza Mirmiran[2], Mahmoud Haghdousti[3], Shahriar Mazhari[4]

ARTICLE INFO

Article history:
Received 18 Aug 2023;
in revised from 26 Aug 2023;
accepted 15 Nov 2023.

Keywords:
Decarbonization, Maritime sustainability, Biofuels, Ecosystem, Digitalization.

ABSTRACT

Decarbonization is crucial to meeting the world's climate goals and a more sustainable future.
As the globe works to cut greenhouse gas emissions and lessen the effects of climate change, decarbonizing the maritime sector has become an urgent problem in recent years.
Fossil fuel combustion is the leading cause of greenhouse gas emissions, which have a role in climate change and global warming. It entails moving away from energy based on fossil fuels and toward greener, lower-carbon options, including renewable energy, energy-saving devices, and sustainable mobility. The necessity of coordination and cooperation between various stakeholders is one of the significant obstacles to decarbonizing the maritime sector.
Governments, shipping firms, and other stakeholders must collaborate to develop and put into practice sustainable solutions because shipping is a global sector. In this research, the author examines the difficulties and possibilities of decarbonizing the shipping sector and the development achieved in this direction. This study investigates the decarbonization prospects available to shipping businesses, the regulatory framework, and alternatives to fossil fuels through a thorough assessment of the literature and data analysis. This article thoroughly analyses the difficulties and potential of decarbonizing the shipping sector, emphasizing fossil fuel alternatives, the regulatory environment, and the options open to shipping businesses for decarbonization. Additionally, it emphasizes the significance of stakeholder cooperation and the contribution of digital technology to the enhancement of shipping operations and the lowering of emissions.

1. Introduction.

1.1. Atmosphere and gases.

Carbon dioxide (CO2) is the primary greenhouse gas emitted through human activities.

Reported by (EPA, 2023) In 2021, CO2 accounted for 79% of all U.S. greenhouse gas emissions from human activities. CO2 is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities are altering the carbon cycle–both by adding more CO2 to the atmosphere and by influencing the ability of natural sinks, like forests and soils, to remove and store CO2 from the atmosphere. While CO2 emissions come from various natural sources, human-related emissions are responsible for the increase in the atmosphere since the industrial revolution. The main human activity that emits CO2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. Specific industrial processes and land-use changes also emit CO2.

Gases that trap heat in the atmosphere are called Green-

[1]Warsash Maritime School, Solent University, UK, E-mail Address: mehrdad.behforouzi@solent.ac.uk.
[2]Warsash Maritime School, Solent University, UK, E-mail Address: reza.mirmiran@solent.ac.uk.
[3]Warsash Maritime School, Solent University, UK, E-mail Address: mahmoud.haghdousti@solent.ac.uk.
[4]Warsash Maritime School, Solent University, UK, E-mail Address: shahriar.mazhari@solent.ac.uk.
[*]Corresponding author: Capt. Mehrdad Behforouzi, Warsash Maritime School, Solent University, East Park Terrace, Southampton SO14 0YN. Email: mehrdad.behforouzi@solent.ac.uk.

house Gases (GHG). This section provides information on emissions and removals of the leading GHG to and from the atmosphere.

- CO2: It enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees, and other biological materials, and also as a result of specific chemical reactions (e.g., cement production). CO2 is removed from the atmosphere (or "sequestered") when plants absorb it as part of the biological carbon cycle.
- Methane (CH4): Methane emits while producing and transporting coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, land use, and the decay of organic waste in municipal solid waste landfills.
- Nitrous oxide (N2O): It pours out during agricultural, land use, and industrial activities; combustion of fossil fuels and solid waste; and during treatment of wastewater.
- Fluorinated gases: Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, potent GHG that emit from various household, commercial, and industrial applications and processes. Fluorinated gases (especially hydrofluorocarbons) are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). Fluorinated gases are typically emitted in smaller quantities than other GHG but are potent GHG. Global Warming Potentials (GWPs) that usually range from thousands to tens of thousands, they are sometimes referred to as high-GWP gases because they trap substantially more heat than CO2 for a given amount of mass (Epa, 2023).

Decarbonization entails ceasing fossil fuels, the primary source of GHG that raise global temperatures and threaten or destroy ecosystems that support life. Ending fossil fuel usage necessitates reengineering manufacturing techniques and, subsequently, products (Martin et al., 2023).

1.2. State shift.

The Arctic is going through a "state shift," a period of rapid change leading to a new stable state. It is becoming increasingly apparent that the Arctic, as we currently know, is being replaced by a warmer, wetter, and more unpredictable environment with each passing year of data. The following three points are the alterations that scientists expect in the future (Greenfacts, 2022):

1. The Arctic Ocean may be free of sea ice in the summer by the late 2030s.
2. The Intergovernmental Panel on Climate Change (IPCC) forecasts of the rise in the ocean's level were likely underestimated, according to subsequent findings of additional melting mechanisms affecting Arctic and Antarctic glaciers, ice caps, and ice sheets.
3. The weather changes in mid-latitudes. It can also affect the formation and strength of tropical storms.
4. Meltwater from Arctic glaciers, ice caps, and the Greenland ice sheet also impacts climate by flooding the ocean with fresh water, which affects ocean water circulation and weather patterns. Melting Arctic land ice (glaciers and ice sheets) is expected to accelerate global sea-level rise, affecting coastal communities, low-lying islands, and ecosystems.
5. In addition, the Arctic serves as both a source and a sink for GHG.

According to new estimations, Arctic soil contains roughly half of the world's soil carbon.

Changes in the amounts of GHG stored or released in the Arctic area, such as CO2 and methane, can thus have a long-term impact on world climate.

2. Literature Review.

2.1. Shipping sector.

About three per cent of all greenhouse gas emissions worldwide attribute to the shipping sector, almost equal to Japan's yearly emissions. More than one hundred thousand large ships propelled by fossil fuels on the ocean account for most of the industry's emissions, which, without decarbonization measures, might reach more than double by 2050 (Dinneen.J, 2022a).

International shipping relies on fossil fuels as an industry, particularly Heavy Fuel Oil (HFO), burning around three hundred million metric tons annually and emitting approximately one billion metric tons of CO2. It means that emissions from international shipping account for 2-3% of global emissions annually (Bingham, 2023a).

It is crucial to reduce the shipping industry emissions to reduce the effects of climate change.

Decarbonization is a crucial stage in the process of tackling the climate disaster that the world is currently experiencing. Since the industrial revolution, CO2 emissions from burning fossil fuels have considerably increased, and if unchecked, they might have disastrous effects on the world and its inhabitants.

The following are some of the consequences of climate change, per a report from the World Health Organization (WHO, 2021):

- The social and environmental determinants of health, such as clean air, safe drinking water, enough food, and adequate shelter, are impacted by climate change.
- Climate change will result in an additional two hundred fifty thousand deaths per year between 2030 and 2050, mostly from starvation, malaria, diarrhea, and heat stress.
- Between USD two to four billion/ year in direct health damage expenses are projected by 2030 (i.e., excluding costs in health- determinating industries like agriculture and water and sanitation).

Decarbonization includes lowering or eliminating these emissions by switching to cleaner, low-carbon options, including renewable energy, energy-efficient technologies, and sustainable transportation.

2.2. Regulatory bodies.

Member States of the IMO (IMO, 2023), meeting at the Marine Environment Protection Committee (MEPC 80), have adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships, with enhanced targets to tackle harmful emissions. The revised IMO GHG Strategy includes the following:

- An enhanced common ambition to reach net-zero GHG emissions from international shipping close to 2050.
- A commitment to ensuring the uptake of alternative zero and near-zero GHG fuels by 2030.
- Indicative checkpoints for 2030 and 2040.

According to (UNEP, 2021) and to avoid these consequences, the world needs to reduce its greenhouse gas emissions and limit global warming to well below 2°C above pre-industrial levels, as outlined in the Paris Agreement. Decarbonization is essential to achieving this goal. It involves transitioning away from fossil fuel-based energy sources and adopting cleaner, low-carbon alternatives such as renewable energy, energy-efficient technologies, and sustainable transportation.

The Paris Agreement calls for limiting global warming to below two degrees over pre-industrial levels and reducing greenhouse gas emissions worldwide to prevent severe consequences.

Decarbonization is necessary to do this. It entails shifting away from energy sources based on fossil fuels and embracing greener, lower-carbon substitutes like renewable energy, energy-efficient technologies, and environmentally friendly transportation (UNFCCC, 2015).

3. Methodology.

This study thoroughly analyses the literature in scholarly journals, business reports, and official government publications. Several databases, including Google Scholar and Web of Science, were used to review the literature. Relevant keywords, such as ”decarbonization,” ”shipping,” ”alternative fuels,” ”regulations,” ”zero-emission ships,” and ”digital technologies” were used.

The data analysis identifies obstacles, chances, and developments in the decarbonization of the maritime sector. The research also provides instances of efforts and shipping firms that have made progress in lowering emissions.

The results of this study are synthesized to offer a thorough overview of the opportunities and problems associated with decarbonizing the shipping sector, as well as the role that cooperation and digital technologies play in attaining this objective.

4. Findings.

The results of study are as follow:

4.1. Initiatives underway to promote decarbonization in the shipping industry.

1. The Poseidon Principles.
   It is a collection of recommendations for banks on evaluating and disclosing the degree to which their shipping portfolios are climate-aligned. The Global Maritime Forum (GMF) and many central banks, including Citi and Société Générale, created the principles. Banks may encourage shipping businesses to invest in environmentally friendly technologies and lower their emissions by matching their lending portfolios to the objectives of the Paris Agreement. Together, they constitute a bank loan portfolio totaling more than one hundred and five billion USD for international shipping, or nearly 50% of the total ship finance portfolio. (Global Maritime Forum, 2023).
   This measure complied with IMO regulations and encouraged the maritime industry to reduce emissions. In the future, when shipping businesses from other nations seek finance sources, the Poseidon principles will be a crucial signal that financial institutions will consider.
   It will also demonstrate whether significant maritime businesses are taking climate change seriously enough. (Tai et al., 2022)
2. The Sea Cargo Charter.
   It enables signatories to evaluate their current situation more accurately and determine how well they align with IMO objectives. By gathering information, signatories understand their chartering efforts and can better plan for the future. To quantify carbon intensity and total GHG emissions and evaluate their climate alignment, signatories undertake to collaborate with ship owners and business partners to gather and process the information needed. (rightship, 2021).
3. The Getting to Zero Coalition.
   The World Economic Forum, the GMF, and other significant shipping firms have joined forces to form the Getting to Zero Coalition. By 2030, the Coalition wants to hasten the implementation of zero-emission ships. It strives to determine the most promising zero-emission technologies and provide a legal and legislative framework to facilitate their adoption to meet this objective. The Getting to Zero Coalition platform convenes around two hundred stakeholders across the shipping and fuels value chain, which is managed by the GMF and was founded in 2019 with the Friends of Ocean Action and the World Economic Forum after a 2018 Call to Action launched by thirty-four critical stakeholders dedicated to decarbonizing shipping (weforum, 2023).
4. The Green Shipping Programme (GSP).
   GSP a public-private partnership, aims to advance the Norwegian government’s maritime strategies and plans. The programme aims to develop and strengthen Norway’s goal to establish the world’s most efficient and environmentally friendly shipping. It started in January 2015 under “the Green Coastal Shipping Program”, consisting of sixteen private companies and organizations and

two government ministries. In the spring of 2019, the program changed its name to the Green Shipping Program to state its international ambitions. In the spring of 2023, the program included more than a hundred-eight private companies and organizations and twelve public observers. The GSP is financed partly by public allocations from the State budget of Norway and partly by the members themselves (greenshippingprogram, 2021).
Ship owners can effectively reduce carbon emissions in the maritime industry by using green fuels instead of conventional fossil fuels. The majority of green fuel is created from green energy, and the development of renewable energy sources like wind and solar power helps to produce more green fuel. Therefore, transforming the maritime industry into a low-carbon industry depends on green power produced by renewable energy sources. The maritime sector may benefit from the support and development of marine renewable energy power generation technologies and the subsequent production of green fuel under the environmental requirements of ship operation (Shi et al., 2023).

5. The Clean Shipping Alliance.
It is a global association of companies that are committed to reducing emissions from their ships. The alliance focuses on promoting the use of exhaust gas cleaning systems (also known as scrubbers) to reduce sulfur oxide emissions from ships. The alliance works to improve the understanding of scrubber technology and its benefits, and to promote regulatory frameworks that support the use of scrubbers.
According to (Gerlitz et al., 2022), Ammonia (NH3) has excellent potential to develop into a zero-carbon fuel that might be used as part of the future energy mix. Compared to handling and storing hydrogen, another zero-carbon fuel, easy handling, and storage circumstances can be advantageous, particularly in transportation. Additionally, due to the partially developed shoreside infrastructure, the required bunker structure requires less investment than hydrogen. However, the supply and delivery of NH3 in ports come at a high cost because of port storage facilities and more expensive transportation infrastructure. Ammonia exhibits superior handling and storage benefits, enabling lengthy maritime trips without appreciable cargo space loss at an affordable price. The infrastructure required for manufacturing, delivery, and operations of ammonia supply chains and the technology for ammonia-powered vessels is currently under development.

4.2. What are some examples of zero-emission technologies being developed for ships?

1. Hydrogen fuel cells.
A promising solution for ships with zero emissions is hydrogen fuel cells. Fuel cells use the reaction of hydrogen and oxygen to produce energy, with the sole byproduct being water.
All American Marine, Inc. (AAM) and the vessel owner SWITCH Maritime (SWITCH) operate "MV Sea Change", a Seventy-foot, seventy-five passenger, zero-emissions, hydrogen fuel cell-powered, electric-drive ferry that navigates in the California Bay Area. (allamericanmarine, 2023).
2. Battery-electric propulsion.
Battery-electric propulsion systems are already in operation for smaller ships, and larger vessels are also being designed using them.
Batteries are used in battery-electric propulsion systems to store electricity and run the ship's electric motors. Organizations like Norwegian Electric Systems and Corvus Energy are developing battery systems for ships. Norway has a long and illustrious history in shipping and the sea. The Norwegian public and business sectors have thus been eager to take the lead in a green marine transformation for both strategic and historical reasons. Furthermore, nearly all of Norway's electricity comes from renewable sources. It indicates that Norway has sought out industries that help reduce emissions more actively than other nations. Furthermore, Norway's expertise in renewable energy has made it a desirable location for producing energy-intensive goods like batteries (Saether and Moe, 2021).
3. Ammonia fuel.
Ammonia is a carbon-free fuel that can be produced from renewable sources.
A possible alternative fuel for marine diesel engines, ammonia has no carbon and no sulfur in its composition. Recently, NH3 has received much attention from scientists and companies making marine engines. Ammonia has a high auto-ignition resistance, making it challenging for ordinary diesel engines to burn it. High NOX emission, N2O emission, and Ammonia slip are the main problems following ammonia combustion but can be reduced by adopting an ideal combustion environment (Zincir, 2020).
4. Wind power.
The vessel's propulsion can use a renewable energy source like wind. Several businesses are creating wind-assist and wind propulsion systems for ships.
The Wind Assisted Ship Propulsion (WASP) project, which is supported by the Interreg North Sea Europe program and the European Regional Development Fund (ERDF), brings together universities, wind-assist technology providers, and ship owners to research, trial, and validate the operational performance of a selection of wind propulsion solutions on five vessels, enabling the market penetration of wind propulsion technology and promoting a more environmentally friendly North Sea transport system. The 143-meter, 1036 TEU feeder container ship "MV Kalamazoo", which Norse owns, will receive two 10.5-by-2.8-meter containerized Ventofoils (an upgraded Ventifoil) wind assist units from Econowind by the end of 2023, according to an announcement made in April by the Singapore-based Ocean Network Express (northsearegion, 2023).

According to (Vigna and Figari, 2023) the case study conducted under moderate wind conditions in the Mediterranean, advantages through WASP under ship design circumstances would range from 5% to 10% in terms of power savings and from 4% to 6% in terms of fuel usage. Using rotors and Controllable Pitch Propeller (CPP) together may reduce fuel consumption by up to 15% if reduced operational speeds (10–12 knots) are acceptable.

5. Biofuels.
   Biofuels are renewable fuels that can be produced from organic matter, such as algae or crop waste. Several companies, including GoodFuels and Neste, are developing biofuels for use in ships. Biofuels are clean, sustainable fuels made from plant waste or other organic materials like algae. Biofuels are being developed for use in ships by some businesses, including GoodFuels and Neste.
   A new tool from Neste, Neste Marine 0.1 Co-processed, enables maritime firms to minimize their GHG emissions by up to 80% throughout their lifecycles compared to fossil fuels. They are created using traditional refining and partially substituting renewable raw materials for fossil-based ones. The market offers three primary biofuel alternatives and low-emission co-processed bunker fuels (Neste, 2023).

   - The first is Hydrotreated Vegetable Oil (HVO), primarily from leftovers and waste materials like discarded vegetable oils and animal fats.
   - The second is Trans-esterified fuels like Fatty Acid Methyl Esters (FAME).
   - The third type is crude biofuel, which includes fuels produced from soy, rapeseed, palm, fish, and other fats.

   HVO generally emits less engine-out CO, HC, and soot under all examined conditions. Benefits over conventional petroleum-derived diesel tend to intensify at low coolant temperatures, with diesel emissions rising more sharply than HVO during cold starts and at "artificially" decreased coolant temperature conditions. Furthermore, at both high and low coolant temperatures, HVO appears to be more tolerant of variations in engine calibration parameters than diesel. HVO emission trends tend to be flatter than diesel, exhibiting sharper deterioration at the calibration ranges' lower or higher ends of calibration ranges (Mancarella and Marello, 2022).
6. Big Data Analysis (BDA). Ship operators can identify energy inefficiencies in maritime operations, such as poor route planning, excessive fuel use, or inefficient equipment utilization, using real-time digitally recorded sensor data analysis.
   According to (Jovic et al., 2019) BDA enables ship owners to determine the optimum speed for fuel consumption, efficient routing, and improving shipping efficiency.
7. Artificial Intelligence (AI) - powered energy management systems.
   AI applications can optimize energy usage by predicting energy demands, optimizing on-board systems, and providing real-time recommendations to captains and crew members. These AI systems continuously learn from data to enhance energy efficiency over time.
   Enabling digital technologies such as blockchain, AI and machine learning, the Internet of Things (IoT), and broadband, low latency satellite connectivity have progressed so rapidly that their impact on decarbonisation still needs to be fully appreciated in some parts of the maritime sector. Shipping must harness the readily available power of digital technologies to decarbonise conventional ships today, optimising the pathway to 2050 and accelerating the rate of change required to achieve the targets set by the international community (Inmarsat, 2022).
8. Carbon Capture and Storage (CCS).
   Underground storage of CO2 emissions from industrial operations and power plants is known as CCS. It can aid in lowering emissions from industries like steel and cement that are challenging to decarbonize.
   In the direct capture of CO2 from the air, the high dilution level of CO2 in the air (0.04%) increases the energy requirement and cost of the process compared to carbon capture from flue gases (with CO2 concentrations around 15% for coal power plants). Thus, investing in direct capture can have a more significant impact on emission reduction. Pre-combustion capture is typically more efficient due to the more concentrated CO2. Still, the capital costs of the base gasification process are often more expensive than traditional pulverised coal power plants. Amine scrubbing removes CO2 and converts it to fuel, a fuel feedstock to supply energy, which will, in turn, contribute to emissions. Hence using a renewable source of energy optimise this process. Carbon reutilization incentivises the industry to invest in carbon capture technology as they profit from using their emissions as feedstock (Bhate and Joseph, 2023).
9. Carbon Pricing.
   Carbon pricing includes assigning a cost to carbon emissions to encourage businesses and people to lessen their carbon impact. Carbon taxes or cap-and-trade programs can accomplish this.
   According to (Xiayimulati, 2023) Carbon pricing in the energy and fuel sector will encourage converting conventional coal energy to clean energy and hasten the development of a low-carbon and ecologically friendly society. The political context, public acceptance, the global unified normative framework, and other areas all provide difficulties for carbon pricing. Although carbon pricing has many difficulties, it is an essential strategy for combating climate change and upholding sustainable development. Through multifaceted changes and adjustments of nations, people, businesses, and institutions, carbon pricing will undoubtedly play a significant role.
   However, there must be clear environmental policies available to use Carbon pricing.
   The question is not whether carbon pricing is desirable

but whether carbon pricing policies are environmentally effective (Boyce et al., 2023).

10. Improving the ships design.
Improving the ships design can also contribute to decarbonization by reducing the bunker's consumption. A cutting-edge new propeller with variable pitch offers an economical way to cut greenhouse gas emissions from marine transportation (UKRI, 2023).

4.3. Countries, shipping companies, organizations and classification authorities that are already starting actions.

- Two huge cruise ships, "Celebrity Apex" and "Symphony of the Seas", will start their European journey utilizing sustainable biofuel to partially cover the ships' fuel requirements, according to a statement from United States-based cruise industry leader Royal Caribbean Group (Čučuk, 2023).

- According to (Gcformd, 2023), the Global Centre for Maritime Decarbonisation (GCMD) and Nippon Yusen Kabushiki Kaisha (NYK) signed a five-year Strategic Partnership agreement on 4th July 2023. This significant partnership strengthens the centre's capacity and efforts to conduct low-carbon solution pilots and trials to provide clear and specific pathways to the decarbonization of the global shipping industry. Japan is one of the world's top three shipowners, with Japanese merchant vessels accounting for approximately 11% of international tonnage. Japan leads other countries in alternative-fuel-ready vessel orders, accounting for roughly 10% of the global equivalent.

- Canada aims to achieve net zero emissions by 2050, and it is developing a national action plan, called the 2030 Emissions Reduction Plan, to align emissions reductions in the marine sector with this goal. The government created the Canadian Green Shipping Corridors Framework to support these pledges, and it also includes direct actions the government is taking to cut emissions from its vessels. (Mandra, 2023)

- According to (maritimeexecutive, 2022), The world's first fully electric and zero-emission fast ferry, classed as a high-speed craft, completed construction, and delivered to its new homeport in Stavanger, Norway. The vessel, "MV *Medstraum"*, began regular commuter service in Norway in the summer of 2022 to demonstrate future electric ferries further.

- With twelve methanol-powered container ships purchased, CMA CGM, Walmart's primary ocean shipping provider, overtook Maersk as the company with the most orders for zero-emission ships. As part of its climate policy, the business declared in June last year that it had bought six ships with dual-fuel methanol engines (Ajot, 2023).

- Some businesses are considering CCS technologies to reduce their emissions. The Lloyd's Register Maritime Decarbonisation Hub (the Hub) has released a new report that examines how Onboard Carbon Capture, Utilisation, and Storage (OCCUS) solutions might be able to serve as a significant mid-term "step" measure for shipping's transition to carbon neutrality. OCCUS technologies have the most significant promise for use with existing vessels because they offer a way to extend the useful lives of these assets without incurring the high cost of switching to zero-carbon fuels (Lr, 2023).

- The company has announced today that the technology group Wärtsilä has received its first order for carbon capture and storage-ready scrubber systems - CCS- Ready scrubbers. The Wärtsilä's received the order in November 2022; the expected delivery is in 2023. Four 8,200 TEU container vessels built at an undisclosed Asian-based yard will be fitted with Wärtsilä's CCS-Ready 35MW scrubber in an open loop configuration (Wartsila, 2023).

- Amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI entered into force on 1 November 2022. Developed under the Initial IMO Strategy on Reduction of GHG Emissions from Ships agreed in 2018, these technical and operational amendments require ships to improve their energy efficiency in the short term and thereby reduce their greenhouse gas emissions. From 1 January 2023, all ships must calculate their attained Energy Efficiency Existing Ship Index (EEXI) to measure their energy efficiency and initiate the collection of data to report their annual operational Carbon Intensity Indicator (CII) and CII rating (IMO, 2022).

4.4. Challenges and costs involved with decarbonization.

1. Complexity.
Decarbonizing the shipping industry is a complex task that requires collaboration between governments, shipping companies, and other stakeholders. One of the biggest challenges is finding alternative fuels that are both sustainable and cost-effective. Currently, most ships run on HFO, which is a cheap but highly polluting fuel. Shipowners have been experimenting with alternative fuels such as Liquefied Natural Gas (LNG), biofuels, and hydrogen, but these fuels have their own challenges. For example, LNG produces fewer emissions than HFO, but it still emits GHG and is a fossil fuel. Biofuels are renewable and emit less GHG, but they require large amounts of land and water to produce. Hydrogen is a promising alternative, but it is expensive to produce and store. The high price of modern infrastructure and technologies is another difficulty. It can be expensive to retrofit old ships with new engines or fuel systems, and building new vessels run on alternative fuels can be considerably more costly. Compared to traditional fossil fuels, this expense may dissuade shipping businesses from investing in greener technologies.
The IMO aims to cut GHG emissions from the shipping sector by 50% by 2050. Still, the group has come under fire for not acting more quickly.

By enacting stricter pollution rules, some nations and regions are taking matters into their own hands. For instance, the European Union has suggested a target of at least a fifty- five percent reduction in shipping emissions by 2030. (Europeancommission, 2021).

2. Costs involved.
   One of our biggest challenges is the current cost differential between conventional and zero-emissions fuels. The cost of alternative fuels in the maritime sector is prohibiting the pace of decarbonisation. There is also a need for more significant investment in research, innovation, and digital adoption to help improve technologies that increase productivity throughout green corridors, ensuring they generate a positive return on investment. (Marineinsight, 2023)
   Over the following decades, the shift of the maritime ecosystem to scalable zero-emission fuels will impact international trade. While the change will result in a more distributed energy supply and associated export potential for scalable zero-emission fuel producers, it will switch to more expensive fuels, influencing trade prices. For the firm to be sustainable, this will ensure that global trade efficiently bears its environmental costs. However, this will raise freight costs globally, having a wide range of effects on different regions, commodities, and trade routes (Bingham and Mikkelsen, 2023).
   More than $1 trillion investment would be required to decarbonize the shipping industry by 2050, according to a report released on 21 September 2022 at the GMF summit in Brooklyn (Dinneen, 2022b).
3. Ammonia bunkering dangers.
   Since NH3 is poisonous, caustic, and explosive, using it as fuel raises safety concerns distinct from those associated with using standard fuels.
   The shipbuilders must use suitable materials to prevent corrosion caused by Ammonia. However, a thorough risk assessment is necessary to understand the effects of poisonous gas dispersion and fire fully. Weather circumstances, leak characteristics, exterior structure, and traffic conditions are just a few of the variables that must be reviewed and rated in order of importance when it comes to the release and distribution of Ammonia. It is also necessary to update the current safety regulations for ammonia bunkering (Duong et al., 2023).

4.5. New Opportunities for Latin America.

As stated by (Bingham, 2023b), Assuming the maritime ecosystem transitions entirely from HFO to green ammonia, this would represent over nine hundred million tons yearly, more than five times today's total global output of conventional ammonia. It reflects the emergence of a new trillion-dollar market opportunity, with countries that can produce green hydrogen, the basis for all scalable zero-emission fuels, at the lowest cost, with a massive potential to supply the fuels needed to decarbonise the international maritime value chain ultimately. Consequently, maritime decarbonisation presents a wide range of opportunities connected to supplying these fuels domestically, exporting these to areas of the world with less renewable potential and ultimately leveraging international maritime decarbonisation to accelerate the transition to renewable forms of energy regionally.

- Latin America has some of the most ideally suited areas for producing green fuels competitively and at scale, given the abundance of renewable energy resources like solar and wind.
- Many countries in the region have high climate ambitions to tap into these resources to power their national electricity grids and switch to cleaner forms of energy.
- Significantly few projects in Latin America are developing green fuels or focusing on shipping's decarbonisation. Further efforts will be needed to ensure the region maintains pace with global developments.
- With coordinated political efforts, Latin American countries could become leaders in green fuel production and export, benefiting from investment opportunities for this new market.

Conclusions

The results of this study assist the author in following up on the study's objective. The following are a few recommendations that may help to create a pathway for achieving the decarbonization goals in the maritime sector:

- Shipping corporations should conduct a feasibility study to assess the viability of various zero-emission solutions for their fleet and operations. The study should consider elements including ship size and type, travel routes and lengths, fuel consumption, and environmental effects. Consequently, they shall create a roadmap with a timeline for introducing zero-emission technology later.
- To choose the most affordable and practical technology, shipping companies should compare the costs and supply of various fuels and infrastructure choices, such as hydrogen refueling stations, battery charging infrastructure, and biofuel production facilities.
- When evaluating the legal requirements for emissions reduction and the incentives and policies supporting the deployment of zero-emission technology, shipping companies should consider the regulatory environment in which they operate, including international, national, and local regulations.
- Suppliers, clients, and investors are just a few stakeholders that shipping companies should work with to discover possibilities and difficulties for reducing emissions. Collaboration can aid in identifying shared priorities and goals and knowledge and skill sharing.

- Shipping companies can collaborate with maritime universities, including vocational colleges and specialized maritime training facilities, to provide access to top-notch training resources and knowledge.

- The training requirements for seafarers and shore staff, as well as the knowledge and abilities needed to operate new zero-emission technologies, should be determined by shipping companies.

- Shipping companies should develop a comprehensive training plan based on the identified training needs, including theoretical and practical training. The training plan should also include information on the safety procedures and best practices for operating new zero-emission technologies. Based on that, create a thorough training program that includes theoretical and practical instruction based on the identified training needs.

- Access to training tools, including manuals, simulators, and chances for on-the-job training, should be made available to their employees (at sea and ashore) by ship owners.

- To ensure that staff are qualified to operate and maintain new zero-emission technologies, ship owners should assess the success of their training programs.

- Ship owners can encourage their staff to participate in learning and professional development by offering bonuses, promotions, or recognition programs.

- Once zero-emission technologies are in place, shipping companies should monitor and evaluate their performance to ensure they meet their emissions reduction goals. The monitoring and evaluation process should include regular reporting and analysis of emissions data and feedback from stakeholders and customers.

- In addition to providing new course modules for the cadets to ensure they have the necessary expertise to operate and maintain the latest equipment, the marine institution and colleges must ensure that its professors and instructors are up to speed with zero-emission technologies.

- The shipping industry's GHG emissions must be reduced or eliminated, and IMO requires steps to be adopted more quickly, thoroughly, robustly, and strictly.

This paper's findings and recommendations rely on the authors' research. Further investigations, research, and actual trials are to be done by other researchers, investors, maritime industries, and shipping companies.

Acknowledgements.

The authors gratefully acknowledge the support from the Warsash Maritime School - Solent University.

References.

Ajot. (2023). CMA CGM Pulls Ahead in Zero-emission Ocean Shipping Race, Still Trails Maersk in Reducing LNG Fleet [online]. Available from: https://www.ajot.com/news/cma-cgm-pulls-ahead-in-zero-emission-ocean-shipping-race-still-trails-maersk-in-reducing-lng-fleet.

Allamericanmarine. (2023). AAM + SWITCH Maritime Announce the Launch of Sea Change, the World's First Commercial Vessel Powered 100% by Hydrogen Fuel Cells [online]. Available from: https://www.allamericanmarine.com/hydrogen-vessel-launch/.

Bhate, A., Joseph, E., (2023). Decarbonizing the Future: Understanding Carbon Capture, Utilization, and Storage Methods [online]. Available from: https://wjaets.com/sites/default/files/WJAETS-2023-0020.pdf.

Bingham, C., Mikkelsen, T., (2023). Understanding Maritime Decarbonization's Impacts on Trade Costs to Unlock a Just Transition [online]. Available from: https://unctad.org/news/-transport-newsletter-article-no-107-understanding-maritime-decarbonization.

Bingham, C. (2023). Global Maritime Decarbonisation: New Opportunities for Latin America [online]. Available from: https://www.globalmaritimeforum.org/news/global-maritime-decarbonisation-new-opportunities-for-latin-america

Boyce, J., Ash, M., Ranalli, B., (2023). Environmental Justice and Carbon Pricing: Can They Be Reconciled? [online]. Available from: https://onlinelibrary.wiley.com/doi/10.1002/g-ch2.202200204

Čučuk, A. (2023). Celebrity Apex and Symphony of the Sea to Set Sail Using Sustainable Biofuel [online]. Available from: https://www.offshore-energy.biz/celebrity-apex-and-symphony-of-the-sea-to-set-sail-using-sustainable-biofuel/

Dinneen, J. (2022). Decarbonising the Shipping Industry Will Cost More Than $1 Trillion. [online]. Available from: https://www.newscientist.com/article/2339247-decarbonising-the-shipping-industry-will-cost-more-than-1-trillion/

Duong, P., Ryu, B., Song, M., Nguyen, H., Nam, D., Kang, H., (2023). Safety Assessment of the Ammonia Bunkering Process in the Maritime Sector: A Review [online]. Available from: https://www.mdpi.com/1996-1073/16/10/4019.

EPA. (2023). Overview of Greenhouse Gases [online]. Available from: https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

Europeancommission. (2021). A European Green Deal-Striving to be the First Climate-Neutral Continent [online]. Available from: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Gcformd. (2023). NYK joins GCMD as first Japan-headquartered partner to accelerate shipping's decarbonization [online]. Available from: https://www.gcformd.org/post/nyk-joins-gcmd-as-first-japan-headquartered-partner-to-accelerate-shipping-s-decarbonisation.

Gerlitz, L., Mildenstrey, E., Prause, G., (2022). Ammonia as Clean Shipping Fuel for the Baltic Sea Region [online]. Available from: https://www.researchgate.net/publication/3587-

24742_Ammonia_as_Clean_Shipping_Fuel_for_the_Baltic_Sea_-Region.

Globalmaritimeforum. (2023). Poseidon Principles [online]. Available from: https://www.globalmaritimeforum.org/poseidon-principles.

Greenfacts. (2022). Global Impacts of Climate Change in the Arctic. [online]. Available from: https://www.greenfacts.org/-en/global-impact-arctic-climate/index.htm.

Greenshippingprogramme. (2021). The World's Most Efficient and Environmentally Friendly Shipping [online]. Available from: https://greenshippingprogramme.com/about-greenshipping-programme/.

IMO. (2023). International Maritime Organization (IMO) adopts revised strategy to reduce greenhouse gas emissions from international shipping. [online]. Available from: https://www.-imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx

IMO. (2022). EEXI and CII - Ship Carbon Intensity and Rating System [online]. Available from: https://www.imo.org/en-/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx

Inmarsat. (2022). The Optimal Route the Why and How of Digital Decarbonisation in Shipping [online]. Available from: https://www.inmarsat.com/content/dam/inmarsat/corporate/documents/maritime/insights/Inmarsat_Thetius_Digital_Decarbonisation_Report_2022.pdf.gc.pdf

Jovic, M., Tijan, E., Marx, R., Gebhard, B., (2019). Big Data Management in Maritime Transport [online]. Available from: https://hrcak.srce.hr/clanak/338474

LR. (2023). Onboard Carbon Capture and Storage [online]. Available from: https://www.lr.org/en/knowledge/research-reports/onboard-carbon-capture-and-storage-a-readiness-assessment-for-the-shipping-industry/.

Mancarella, A., Marello, O., (2022). Effect of Coolant Temperature on Performance and Emissions of a Compression Ignition Engine Running on Conventional Diesel and Hydrotreated Vegetable Oil (HVO) [online]. Available from: https://www.mdpi.com/1996-1073/16/1/144.

Mandra, J. (2023). Canada Positioned to be a Maritime Decarbonization Trailblazer, Study Reveals [online]. Available from: https://www.offshore-energy.biz/canada-positioned-to-be-as-a-maritime-decarbonization-trailblazer-study-reveals/?utm_-source=worldmaritimenews&utm_medium=email&utm_campaign=newsletter_2023-06-22.

Marineinsight. (2023). Study on Decarbonisation of Maritime Industry Highlights Collaboration and Investment as Key [online]. Available from: https://www.marineinsight.com/shipping-news/study-on-decarbonisation-of-maritime-industry-highlights-collaboration-and-investment-as-key/.

Maritimeexecutive. (2022). World's First Electric Fast Ferry is Ready to Enter Service [online]. Available from: https://www.-maritime-executive.com/article/world-s-first-electric-fast-ferry-is-ready-to-enter-service.

Martin, J., Baccarani, C., Brunetti, f., (2023). Sustainability and Decarbonization: Can We Afford It? Some Implications for Management. Available from: https://www.researchgate.net/publication/369792714_Sustainability_and_decarbonization_can_we_afford_it_Some_implications_for_management.

Neste. (2023). Towards Sustainable Shipping with Low Emission Solutions [online]. Available from:https://www.neste.-com/products/all-products/marine/towards-sustainable-shipping#-64249c03.

Northsearegion. (2023). WASP News, Putting the Sail Back into Sailing [online]. Available from: https://northsearegion-.eu/media/23733/wasp-newsletter-6-may-2023.pdf

Rightship. (2021). Best Practise: What is the Sea Cargo Charter and how can it help you? [online]. Available from: https://rightship.com/insights/best-practise-what-is-the-sea-cargo-charter-and-how-can-it-help-you

Saether, S., Moe, E., (2021). A Green Maritime Shift: Lessons from the Electrification of Ferries in Norway [online]. Available from:https://www.researchgate.net/publication/354511907-_A_green_maritime_shift_Lessons_from_the_electrification_of_ferries_in_Norway.

Shi, J., Zhu, Y., Feng, Y., Yang, J., Xia, C., (2023). A Prompt Decarbonization Pathway for Shipping: Green Hydrogen, Ammonia, and Methanol Production and Utilization in Marine Engines [online]. Available from: https://www.mdpi.com-/2073-4433/14/3/584.

Tai, H., Chang, Y., Chand, C., Wang, Y., (2022). Analysis of the Carbon Intensity of Container Shipping on Trunk Routes: Referring to the Decarbonization Trajectory of the Poseidon Principle [online]. Available from: https://www.mdpi.com/2-073-4433/13/10/1580.

UNEP. (2021). Emissions Gap Report 2021 [online]. Available from: https://www.unep.org/resources/emissions-gap-report-2021

UNFCCC. (2015). The Paris Agreement. What is the Paris Agreement? [online]. Available from: https://unfccc.int/process-and-meetings/the-paris-agreement

UKRI. (2023). Clean Maritime: Improving Energy Efficiency in Marine Transport [online]. Available from: https://www.ukri.org/news-and-events/responding-to-climate-change/developing-new-behaviours-and-solutions/clean-maritime-improving-energy-efficiency-in-marine-transport/.

Vigna, V., Figari, M., (2023). Wind-Assisted Ship Propulsion: Matching Flettner Rotors with Diesel Engines and Controllable Pitch Propellers [online]. Available from: https://www.-researchgate.net/publication/370892894_Wind-Assisted_Ship_Propulsion_Matching_Flettner_Rotors_with_Diesel_Engines_and_Controllable_Pitch_Propellers.

Wartsila. (2023). Wärtsilä to Deliver its First CCS-Ready Scrubber Systems [online]. Available from: https://www.wartsila.-com/media/news/08-03-2023-wartsila-to-deliver-its-first-ccs-ready-scrubber-systems-3236385

Weforum. (2023). Getting to Zero Coalition [online]. Available from: https://www.weforum.org/projects/getting-to-zero-coalition.

WHO. (2021). Climate Change and Health [online]. Available from: https://www.who.int/news-room/fact-sheets/detail/-climate-change-and-health.

Xiaimulati, A. (2023). Implications and Challenges of Carbon Pricing [online]. Available from: https://bcpublication.org/-index.php/BM/article/view/4170.

Zincir, B. (2020). A Short Review of Ammonia as an Alternative Marine Fuel for Decarbonised Maritime Transportation [online]. Available from: https://www.researchgate.net/publication/346037882_A_Short_Review_of_Ammonia_as_an_Alternative_Marine_Fuel_for_Decarbonised_Maritime_Transportation.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 224–239

ISSN: 1697-4840, www.jmr.unican.es

Structural analysis of wind turbine blade by using finite element method

Kazi Naimul Hoque[1,*], Samin Abrar Chowdhury[1], Syed Assiqul Haque[1]

ARTICLE INFO

Article history:
Received 12 Sep 2023;
in revised from 26 Sep 2023;
accepted 18 Oct 2023.

Keywords:
Wind turbine blade, finite element analysis, composite materials, von-Mises stress, NACA 2412, strain energy.

ABSTRACT

Wind turbine serves as one of the reliable sources of renewable energy converter around the globe. The main purpose of the wind turbine is to extract maximum aerodynamic efficiency utilizing the wind and turbine blade acting as the main factor for harnessing wind energy. To ensure a turbine blade with required structural integrity as well as aerodynamically thin structure, blade material plays a vital role. The blade materials in a turbine blade should have properties like fatigue resistance, low density, and higher strength. In this study, wind turbine blades are designed using SolidWorks software and analysis is performed for six different materials using the finite element method. The materials used here are carbon epoxy, glass polyester, epoxy E-glass, epoxy S-glass, epoxy carbon UD (230 GPa) prepreg, and structural steel. The purpose of this analysis is to explore the nodal deformation and von-Mises stress distribution as well as maximum strain energy. Later, graphical, and tabular results are presented for the target elements, occurring at the most vulnerable region of blade structure. The results are also presented in terms of maximum von-Mises stress, maximum deformation, and total strain energy. The main goal of this study is to validate and compare the above-mentioned materials with conventional ones to select the best material for the wind turbine blade.

1. Introduction.

The wind energy conversion system (WECS) [1] includes wind turbines, generators and other apparatus which converts the kinetic energy from the wind velocity into mechanical energy. The wind turbine extracts kinetic energy by its rotating blade connected with a gear box usually with a high-speed ratio. This extracted mechanical energy is then converted into electrical energy by means of generator [2].

The main purpose of the wind turbine is to extract maximum aerodynamic efficiency utilizing the wind. The number of blades used in a wind turbine proportional to the aerodynamic efficiency. in this context if we increase the blade number from two to three our aerodynamic efficiency will increase approximately 3%. In contrast adding one more blade hardly increases the efficiency but increase the cost. That's why three blade serves an optimum design [3].

Blade acts as the main factor for harnessing wind energy. For maximum aerodynamic efficiency the blades are required to be thin while for structural integrity thick blades are preferable. Also, turbine blades are affected significantly by external forces such as flap and edge loading which triggers tensile and compressive stresses as well as deformation. Flap and edge bending is responsible for 97% of blade damage [4] [5].

To ensure a long and maintenance free life cycle stiffness, fatigue resistance and high strength are a must. Combining different composites materials for blade design both the dynamic and mechanical property can be modified to get the optimum design [6].

In this paper, finite element analysis is conducted for different composite materials on an existing wind turbine blade having airfoil design NACA 2412. Other design factors considered here are-

- For the symmetry of turbine blades, the analysis is conducted on one blade.
- For initial study, blades are considered to have no twist angle.

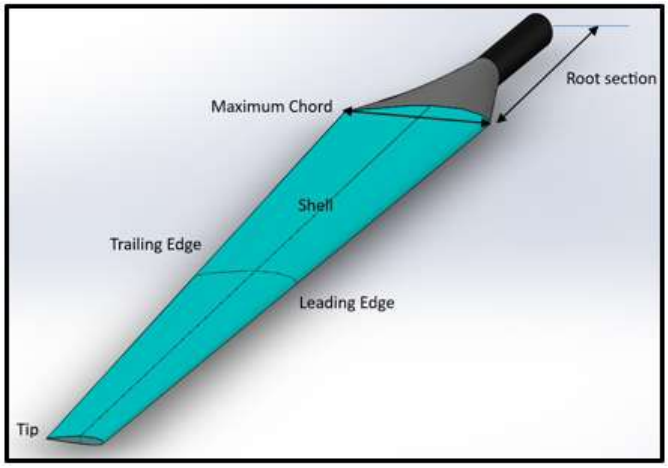
[1]Bangladesh University of Engineering and Technology.
[*]Corresponding author: Kazi Naimul Hoque. E-mail Address: kazinaim@name.buet.ac.bd.

- The wind velocity and load are uniform throughout the blade length.

2. Turbine blade geometry.

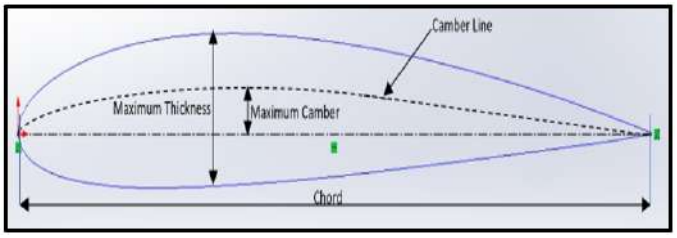
2.1. Blade.

Figure 1: Different parts of wind turbine blade.



Source: Authors.

Figure 2: NACA 2412 airfoil.



Source: Authors.

A wind turbine is a complex structure combining different parts working together to convert the wind energy efficiently. Fig. 1 denotes different parts of a modern wind turbine blade [7].

- Root section- The thick root section is attached to the hub of the turbine. This section is usually thicker than other parts to provide necessary structural strength to the blade. The main purpose is to transmit the rotational forces from blade to hub.
- Shear Web- It is one kind of web which rum along the length of the blade to provide structural rigidity.
- Airfoil section- Airfoil sections are used to shape the blade profile so that the blade profile can achieve proper aerodynamic property. The airfoil sections are designed such way that they generate lift which allows the blade to rotate.
- Shell or Plate- It covers the internal structures and provides aerodynamic shape to the blade as well as provides protection from environmental factors.
- Leading Edge- The front edge of the blade where the wind makes the first contact.
- Trailing Edge- The rare edge where the wind will pass after separating. It needs to be thin and smooth as possible to ensure minimum drag and maximum aerodynamic efficiency.
- Tip- The farthest point from the blade hub. This region moves at the highest velocity.

These above-mentioned parts are considered in this study. Apart from this, to generate a constant lift force with respect to the drag force, a certain twist is given to the blade which is not considered in this study.

2.2. Airfoil design.

The airfoil shape taken in this paper is NACA 2412, as shown in Fig. 2. This profile is developed by National Advisory Committee for Aeronautics (NACA). In general, NACA profiles are used in aviation. But due to their aerodynamic characteristics they ae being widely used as turbine blades [8].

The designation “NACA 2412” stands for-

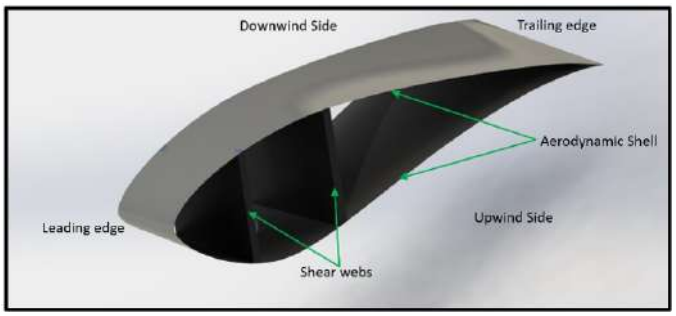
- NACA- National Advisory Committee for Aeronautics, the organization that developed this profile.
- 2 – The first digit represents maximum camber as a percentage of the chord indicated in fig-2. Here, the maximum camber is 2% of the chord length.
- 4 – The second digit represents the location of maximum camber from the leading edge in ten percent of the chord. In this case it is located 40% from the leading edge.
- 12 – the last two digits represent the maximum thickness. Here it is 12% of the chord.

NACA 2412 is being used extensively in wind turbine blade design for having a good compromise between lift and drag. It can provide suitable lift while maintaining reasonable drag levels. Fig. 3 shows the cross-sectional view of turbine blade. In the case of NACA profile, when the wind passes, it creates a pressure difference between the upwind face and downwind face, resulting in lift force.

3. Composite materials.

A composite material is a combination of two or more materials having significantly different properties. Their combination results in better properties than any of the individual material [9] [10].

Figure 3: Cross-sectional view of wind turbine blade.



Source: Authors.

3.1. Advantages of composite materials.

Composite materials provide:

- Higer strength to weight and stiffness to weight ratio than conventional material.
- Better fatigue properties.
- Easier fabrication process for complex structural shapes like turbine blade.
- Higher resistance to impact damage and corrosion.
- Lighter weight and density.

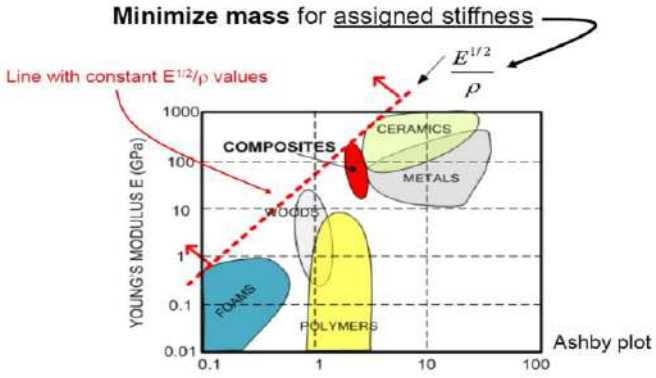
In the above context, today's wind turbine is highly dependable on composite materials to ensure a long and maintenance free life cycle. The question still remains how those properties mentioned above will increase the performance level of wind turbine. To answer that, two factors have to be considered, that is-

1. The blade should be as light as possible because.
   - To lower the fatigue loads induced by gravity.
   - For better performance.
   - Easy transportation and installation.
2. The blade needs to be stiff because.
   - For preventing local or global buckling.
   - For preventing the collision between blade and turbine tower.
   - To withstand both wind and gravity loads. Gravity loads are function of material density hence the weight.

So, an optimization is necessary between the mass and stiffness. Less weight and more stiffness are needed with a balanced aerodynamic and structural integrity. That is the reason for using composite materials. Fig. 4 illustrates that, when considering a constant Young's modulus, composite materials exhibit lower density. Fig. 4 is called "Ashby Plot" [11].

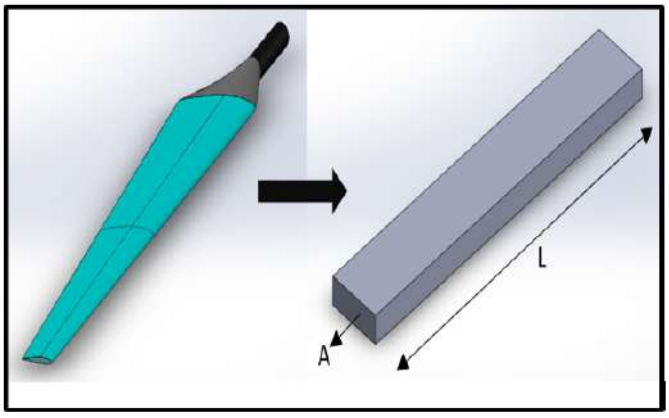
Fig. 4 is governed by the following process.

Figure 4: Ashby plot for different materials [8].



Source: Authors.

Figure 5: Mathematical interpretation of Ashby plot.



Source: Authors.

The assumption here is to consider the blade as a rectangular box of cross-sectional area 'A' and a length of 'L' which can be considered as a beam.

Mass of the beam, $M = AL\rho$

Stiffness of the beam, $S = F/\delta = KEI/L^3$

So, $M = (12S/KL)^{1/2} L^3(\rho/E^{1/2})$

From the above equation it is obvious that for a given stiffness, the mass is inversely proportional to $E^{1/2}/\rho$. For minimizing the mass, it is required to maximize $E^{1/2}/\rho$.

3.2. Commonly used composite materials in wind turbine blades.

- Carbon Fiber Reinforced Polymer (CFRP): Carbon fibers are incorporated into an epoxy-like polymer matrix. In comparison to fiberglass, CFRP has higher stiffness and strength, making it appropriate for larger and more sophisticated turbines.
- Fiberglass Reinforced Polymer (FRP): One of the most often utilized materials is this one. It is made up of glass fibers encased in a polymer matrix, typically polyester or epoxy resin. FRP is strong, long-lasting, and economically advantageous.

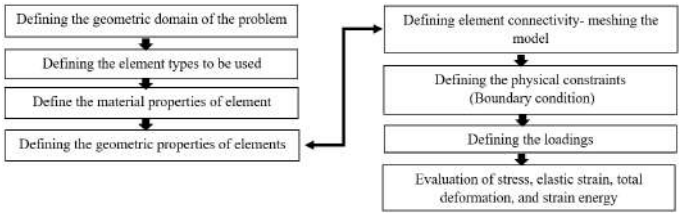
- Glass-Carbon Hybrid: These composite materials combine the advantages of carbon fiber and fiberglass. They offer a balance between price and quality.
- Epoxy Resins: Composites frequently use epoxy as their polymer matrix. It offers strong durability and resilience to external factors, as well as good adhesion to fibers.
- Polyester Resins: These resins offer sufficient mechanical qualities at a reasonable price for smaller wind turbine blades.

In this study, considering our blade size, wind condition, cost consideration; we have taken Carbon Epoxy Composite, Glass Polyester, Graphite Epoxy, E-glass UD, S-glass UD, Epoxy carbon Prepreg and Structural Steel for our analysis.

4. Finite element method.

The Finite Element Method (FEM) is a numerical technique used to solve complex engineering and mathematical problems [12]. It is especially beneficial for studying systems and structures with complex geometries, boundary conditions, and material characteristics. The general procedure is described below.

- Pre-processing step:



- Solution step: In this step, equations are solved using various numerical techniques such as matrix operations and iterative methods. The finite element program calculates the unknown values of the fundamental variables by assembling several governing algebraic equations in matrix form. To calculate other variables, the computed values are further substituted and computed.
- Post-processing step: After the solution step, valuable information can be extracted from the obtained results such as stress distribution, strain, deformation, strain energy and other parameters.

5. Governing equations.

From mathematical standpoint, [13] Finite Element Method (FEM) is a numerical method used for solving a set of related differential equations such as:

The global FEM equation relates the forces and moments acting on all of the mesh nodes (F), the displacements and rotations at all of the mesh nodes (U), that is, all of the degrees of freedom, and the global stiffness matrix (K).

$$[F] = [K]\{U\} \tag{1}$$

Here, the nodal forces [F] is filled with any of the known external loads and the nodal displacement {U} needs to be filled with boundary conditions.

- Stress Calculation:

In FEA, for linear analysis stress is often calculated using Hooke's law, which relates stress (σ) to strain (ε) through the material's elastic modulus (E):

$$\sigma = E{\cdot}\varepsilon \tag{2}$$

For nonlinear operations, FEA simulates the shear, tension, and bending stresses using complicated equations and empirical data. A set of vector equations are used in the software computations to describe how a component would behave under stress. The overall stress response is then created by combining the directional and deformation responses. The analysis's results can be expressed in terms of von-Mises stresses and elastic strains.

- Deformation Calculation:

Linear interpolation is typically used within elements to compute the displacement field.

- Energy Calculation:

In the context of FEA, there are different types of energies that can be calculated, such as strain energy and potential energy.

- Strain Energy:

The strain energy stored in a material due to deformation can be calculated using the formula:

$$U = 1/2 \int V\sigma \cdot \varepsilon \, dV \tag{3}$$

6. Loads on blades.

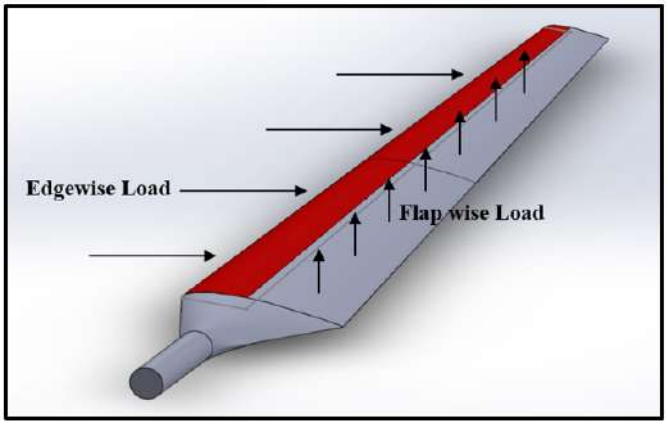
Wind turbine blades are subjected to various loads during their operation. For an efficient performance, it is crucial to understand the effects of these loads [14]. The primary loads on wind turbine blades include:

- Aerodynamic Loads: These are the loads that the wind itself produces. Wind turbine blades must be shaped like an airfoil to produce lift and drag forces in order to capture the kinetic energy of the wind. While the drag force works to prevent motion, the lift force is what propels the blades' rotation. These forces change according to wind direction and speed.
- Gravity Loads: Wind turbine blades are typically quite long and heavy, so they experience gravitational forces. These forces can lead to bending and twisting of the blade.

- Centrifugal Loads: Wind turbine blades experiences these loads due to their circular motion.
- Dynamic Loads: Due to variations in wind speed and direction dynamic load is created on blades.

The above-mentioned loads primarily act flap wise direction and edge wise direction on wind turbine blade.

Figure 6: Loads on blade.



Source: Authors.

Flap wise load:

- Direction: It acts perpendicular to the plane of the blade rotation that is to the upwind part of the blade.
- Causes: Flap wise loads primarily results from aerodynamic forces including lift and drag force generated as wind flows over the airfoil shape blade.
- Effects: It leads to banding of the blade along the length.

Edge wise load:

- Direction: Acts perpendicular to flap wise direction. In this study, the load for edge area is assumed to occur throughout the 40% of total blade face area from the leading edge across the width of the blade. 40% area is taken according to the maximum thickness of the chosen airfoil section.
- Causes: Edge wise loads typically results from gravity and centrifugal forces due to blade's rotation.
- Effects: Edgewise loads can lead to twisting or torsional deformation of the blade.

7. Materials selection.

The properties of structural steel and composite materials are given below:

7.1. Structural steel.

The structural steel is most commonly used for construction of buildings, bridges, steel infrastructure and other industrial structure. It has a high weight to strength ratio, high ductility and quite durable and such characteristics make this material suitable for construction purpose.

Table 1: Properties of structural steel.

Density (g/cm^3)	7.85
Young's Modulus (GPa)	80
Poisson's Ratio	0.29
Shear Modulus	31.008
Tensile Stress (MPa)	450
Shear Stress (MPa)	515

Source: Authors.

7.2. Carbon epoxy.

A carbon epoxy composite, also known as a CFRP (Carbon Fiber Reinforced Polymer), is a high-performance material used in various industries, including aerospace, automotive, sports equipment, and construction. It is made by combining carbon fiber and an epoxy resin matrix.

Table 2: Properties of carbon epoxy .

Density (kg/m^3)	1446.2
Young's Modulus (MPa) E_x	1727
Young's Modulus (MPa) E_y	7200
Young's Modulus (MPa) E_z	7200
Poisson's Ratio v_{xy}	0.3
Poisson's Ratio v_{yz}	0.21
Poisson's Ratio v_{zx}	0.21
Modulus of Rigidity (MPa) G_{xy}	3760
Modulus of Rigidity (MPa) G_{yz}	3760
Modulus of Rigidity (MPa) G_{zx}	3760

Source: Authors.

7.3. Glass polyester.

Glass polyester, often referred to as fiberglass reinforced polyester (GRP), is a composite material composed of polyester resin and glass fibers. This combination results in a material that offers a balance of strength, durability, and corrosion resistance. It is widely used in boat hulls, and automobile parts.

7.4. Epoxy carbon UD (230 GPa) prepreg.

"Prepreg" is short for "pre-impregnated" composite material. It refers to a type of composite material that consists of reinforcement fibers that have been pre-impregnated or pre-coated with a thermosetting resin matrix. Prepregs are commonly used in aerospace, automotive, marine, and other industries where high-performance and precise control over material properties are required. That's why in this study prepreg epoxy carbon is taken.

Table 3: Properties of glass polyester.

Density (kg/m^3)	1960
Young's Modulus (GPa) E_x	48.16
Young's Modulus (GPa) E_y	11.21
Young's Modulus (GPa) E_z	11.21
Poisson's Ratio v_{xy}	0.27
Poisson's Ratio v_{yz}	0.096
Poisson's Ratio v_{zx}	0.096
Modulus of Rigidity (MPa) G_{xy}	4420
Modulus of Rigidity (MPa) G_{yz}	4420
Modulus of Rigidity (MPa) G_{zx}	9000

Source: Authors.

Table 4: Properties of epoxy carbon UD (230 GPa) prepreg.

Density (kg/m^3)	1490
Young's Modulus (GPa) E_x	121
Young's Modulus (gPa) E_y	8.6
Young's Modulus (GPa) E_z	8.6
Poisson's Ratio v_{xy}	0.27
Poisson's Ratio v_{yz}	0.4
Poisson's Ratio v_{zx}	0.27
Modulus of Rigidity (MPa) G_{xy}	4700
Modulus of Rigidity (MPa) G_{yz}	3100
Modulus of Rigidity (MPa) G_{zx}	4700

Source: Authors.

7.5. Epoxy E-glass UD.

An epoxy E-glass composite is a type of composite material that combines E-glass fibers (often referred to as electrical glass fibers) with an epoxy resin matrix. This combination results in a strong, durable, and versatile material with a wide range of applications in aerospace industries.

Table 5: Properties of epoxy E-glass UD.

Density (kg/m^3)	2600
Young's Modulus (GPa) E_x	85
Young's Modulus (GPa) E_y	14
Young's Modulus (GPa) E_z	14
Poisson's Ratio v_{xy}	0.23
Poisson's Ratio v_{yz}	0.4
Poisson's Ratio v_{zx}	0.23
Modulus of Rigidity (MPa) G_{xy}	5000
Modulus of Rigidity (MPa) G_{yz}	3600
Modulus of Rigidity (MPa) G_{zx}	4000

Source: Authors.

7.6. Epoxy S-glass UD.

An epoxy S-glass composite is a type of composite material that combines S-glass fibers with an epoxy resin matrix. This combination creates a high-performance material known for its exceptional strength, durability, and resistance to various environmental factors.

Table 6: Properties of epoxy S-glass UD.

Density (kg/m^3)	2495
Young's Modulus (GPa) E_x	93
Young's Modulus (GPa) E_y	11
Young's Modulus (GPa) E_z	11
Poisson's Ratio v_{xy}	0.23
Poisson's Ratio v_{yz}	0.4
Poisson's Ratio v_{zx}	0.23
Modulus of Rigidity (MPa) G_{xy}	5000
Modulus of Rigidity (MPa) G_{yz}	3900
Modulus of Rigidity (MPa) G_{zx}	5000

Source: Authors.

8. Results and Discussion.

8.1. Specifications of wind turbine blade.

The following Table 7 indicates the specifications of wind turbine blade.

Table 7: Specifications of wind turbine blade.

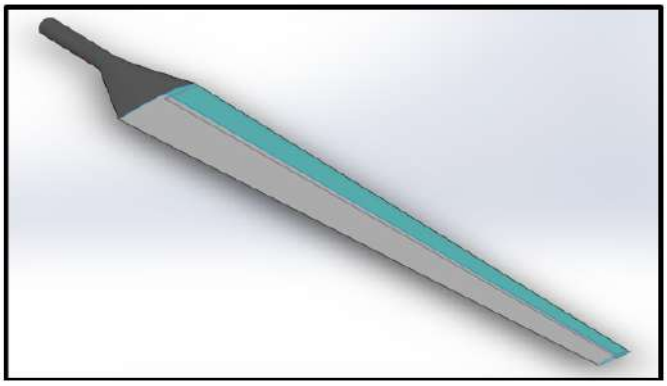
Profile	NACA 2412
Root Chord length	1651 mm
Length of blade	10700 mm
Hub length	1465 mm
Hub Diameter	337.5 mm
Tip Chord length	650 mm
Hub to neck length	1475 mm

Source: Authors.

8.2. Wind turbine blade model.

A 3D geometric model of wind turbine blade is generated in SolidWorks, as shown in Fig. 7.

Figure 7: Blade model.



Source: Authors.

8.3. Load equation.

$$F = \pi \times \rho \times V^2 \times D^2 \tag{4}$$

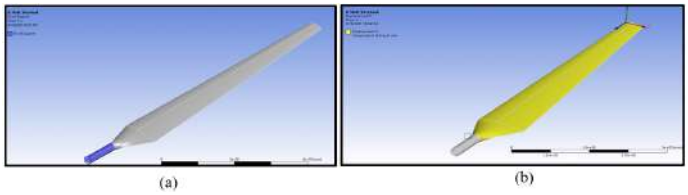
Here,
P = Density = 1.29 Kg/m^3.

V = Wind Velocity = 10 m/s.
D = 30 m.
So, $F = \pi \times 1.29 \times 10^2 \times 30^2 = 364554$ N.

8.4. Boundary conditions.

The Hub of the blade is fixed. So, all six degrees of freedom are constrained here. Also, the displacement along X and Z axes are also constrained for the blade and thus only translatory motion is constrained in these directions. This condition was implied so that the blade itself does not deform along the direction of rotation and towards the center.

Figure 8: a) Fixed support; b) Displacement along X and Z axes are constrained.



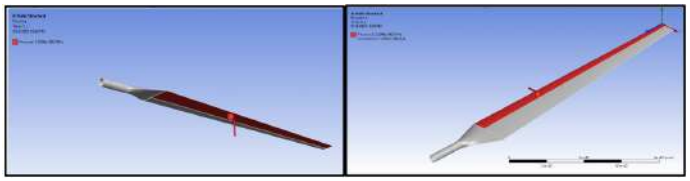
Source: Authors.

8.5. Application of loadings.

For loading, pressure is applied on the edge area of the blade along X axis which is the direction of wind impact and pressure is applied normal to the flap area of the blade.

Edge wise pressure = 0.032842 MPa.
Flap wise pressure = 0.019288 MPa.

Figure 9: Application of flap wise pressure and edge wise pressure.



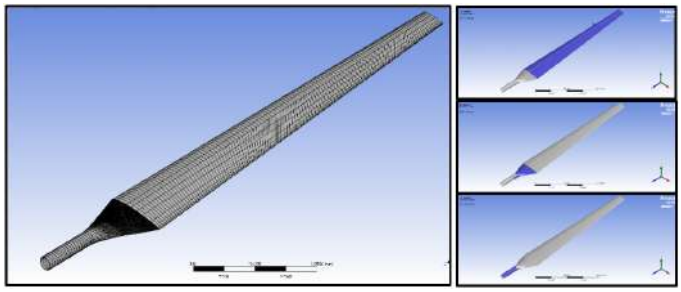
Source: Authors.

It is assumed that the pressure is uniform throughout the area for both flap area and edge area. The pressure for edge area is assumed to occur throughout the 40% of total blade face area from the leading edge and the rest is for flap area where flap wise pressure load is given.

8.6. Meshing.

The entire meshing is done in three parts. Mapped face meshing is generated in each part. The element size for Part A, Part B, Part C; are respectively 0.1m, 0.25m, 0.20m. Quadrilateral method is used for these face meshing. Also, quadrilateral dominant method is used for the entire body with quadratic element order. For the mesh metric of element quality, the max. is 0.99804, the min. is 5.0013e-002, the average is 0.52025 and the standard deviation is 0.27388. The total number of nodes is 16744 and elements are 5566.

Figure 10: Mesh generation of wind turbine blade.

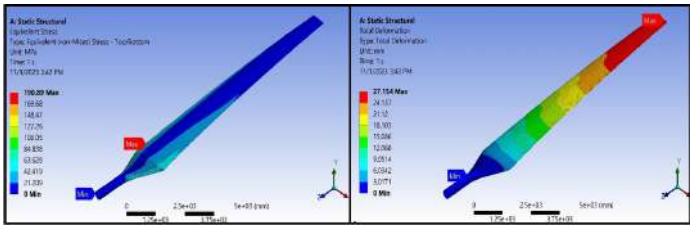


Source: Authors.

8.7. Analysis results.

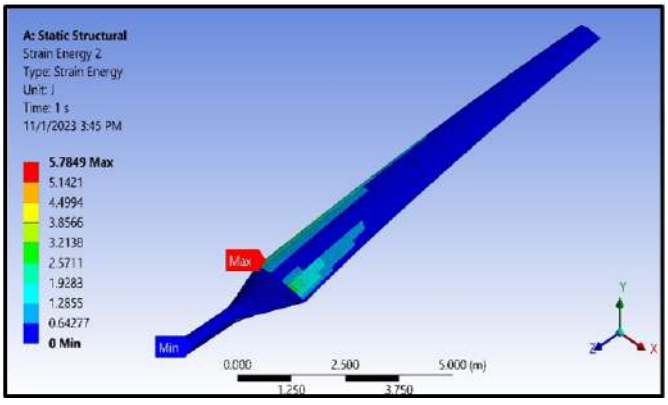
8.7.1. Structural steel.

Figure 11: Total deformation and von-Mises stress distribution of structural steel.



Source: Authors.

Figure 12: Total strain energy distribution of structural steel.

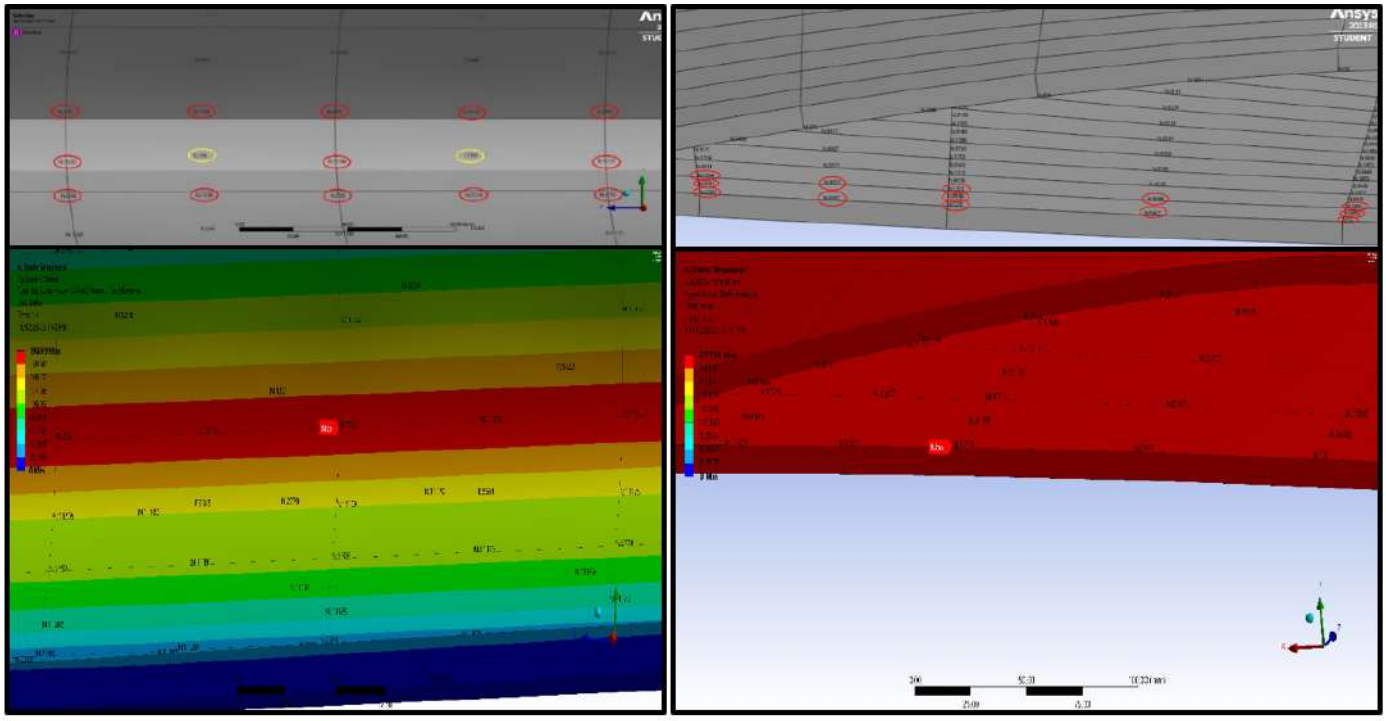


Source: Authors.

The maximum deformation is 27.154 mm, and it occurs at the tip of the blade. The maximum von-Mises stress is 190.89 MPa. Two elements were taken around the node of maximum deformation (Element no 3980 & 4102) and maximum stress (Element no. 3364 & 3365).

The maximum strain energy is 5.7849 J at element no. 3367 and the total Strain Energy is 1341.3 J. The elements and their corresponding nodes are marked in the figure 13 which were taken for nodal analysis. For each element, nodes were taken anti-clockwise and started from the bottom left node, as shown in Table 8.

Figure 13: a) Von-Mises stress distribution to the corresponding nodes (Element No. 3364 & 3365); b) Total deformation to corresponding nodes (Element No. 3980 & 4102).



(a) (b)

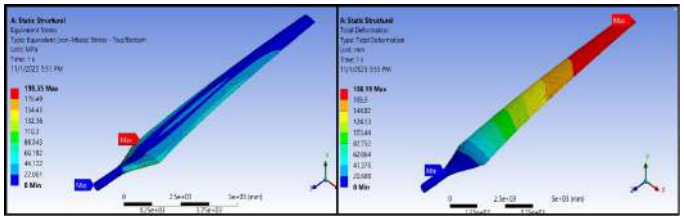
Source: Authors.

Table 8: Element no. and corresponding node no. at the most vulnerable region of structural steel.

Element	Nodes							
3364	2782	11176	2774	11175	2775	11178	2783	11190
3365	2790	11191	2782	11190	2783	11193	2791	11205
3980	1728	5657	19	5658	1858	9189	1723	9188
4102	1729	9197	1728	9188	1723	9187	1724	9191

Source: Authors.

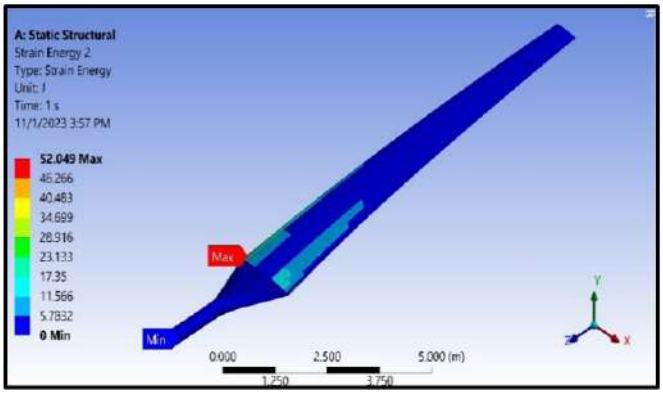
Figure 14: Total deformation, von-Mises stress and strain energy distribution of carbon epoxy.



Source: Authors.

The maximum deformation is 186.19 mm, and it occurs at the tip of the blade. The maximum von-Mises stress is 198.55 MPa. Two elements were taken around the node of maximum deformation (Element no 3980 & 4102) and maximum stress (Element no. 3366 & 3367).

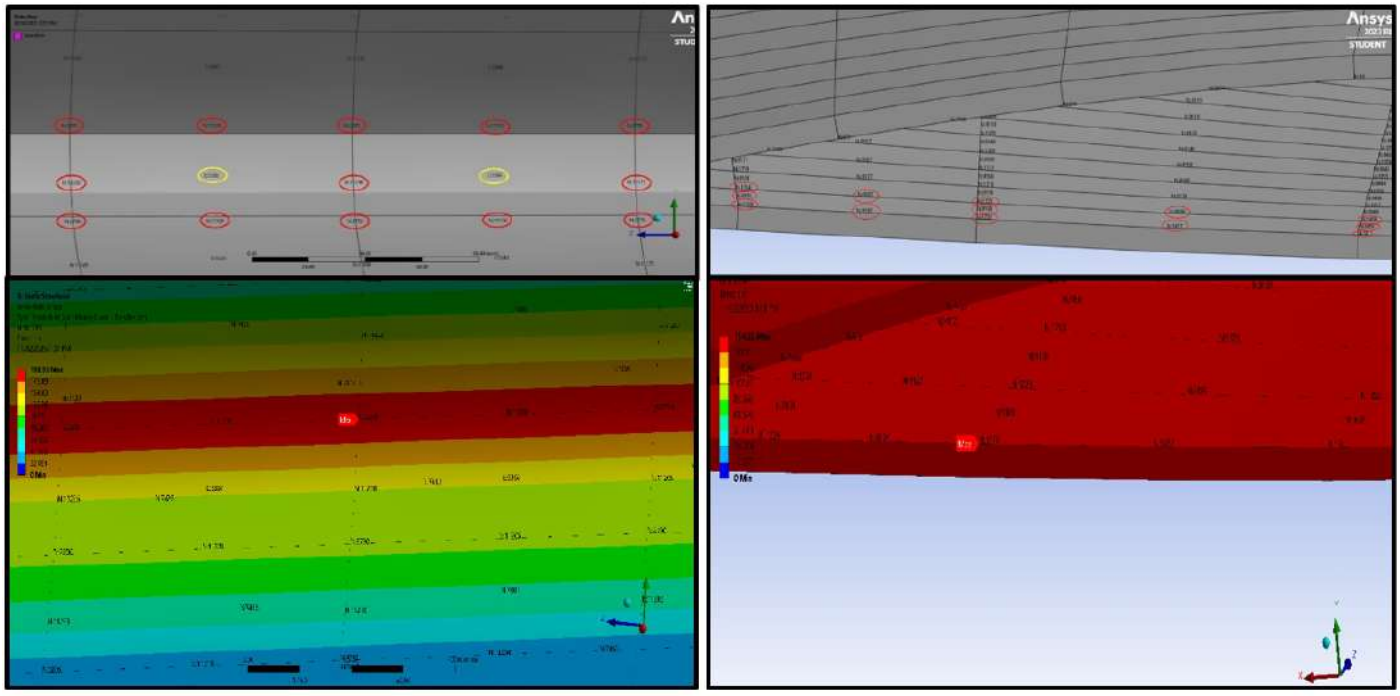
Figure 15: Strain energy distribution of carbon epoxy.



Source: Authors.

The maximum strain energy is 52.049 J at element no. 3368 and the total strain energy is 9301.5 J. Max. stress occurs at node no. 2799 & max. deformation occurs at node no. 1728. The elements and their corresponding nodes are marked in the figure 16 which were taken for nodal analysis. For each element, nodes were taken anti-clockwise and started from the bottom left node shown in Table 9.

Figure 16: a) Von-Mises stress distribution to the corresponding nodes (Element No. 3366 & 3367); b) Total deformation to corresponding nodes (Element No. 3980 & 4102).



(a) (b)

Source: Authors.

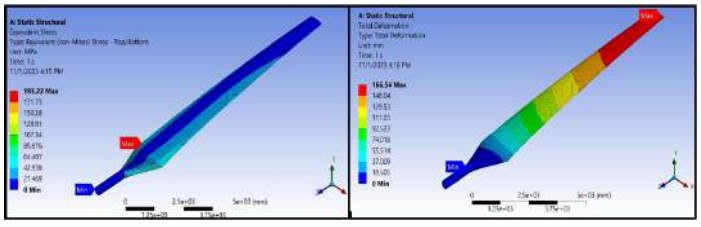
Table 9: Element no. and corresponding node no. at the most vulnerable region of carbon epoxy.

Element	Nodes							
3366	2798	11206	2790	11205	2791	11208	2799	11220
3367	2806	11221	2798	11220	2799	11223	2807	11235
3980	1728	5657	19	5658	1858	9189	1723	9188
4102	1729	9197	1728	9188	1723	9187	1724	9191

Source: Authors.

8.7.2. Glass polyester.

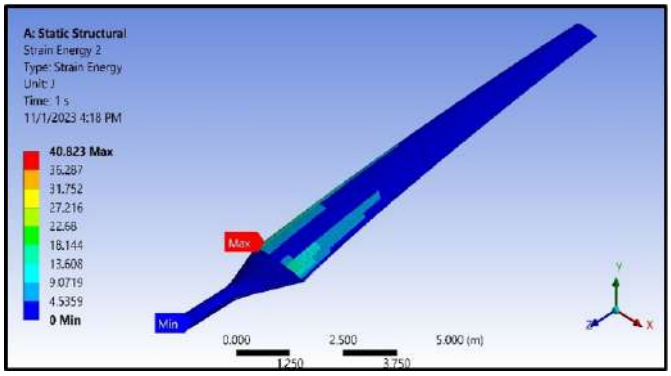
Figure 17: Total deformation and von-Mises stress distribution of glass polyester.



Source: Authors.

The maximum deformation is 166.54 mm, and it occurs at the tip of the blade. The maximum von-Mises stress is 193.22 MPa. Two elements were taken around the node of maximum deformation (Element no 3980 & 4102) and maximum stress (Element no. 3366 & 3367).

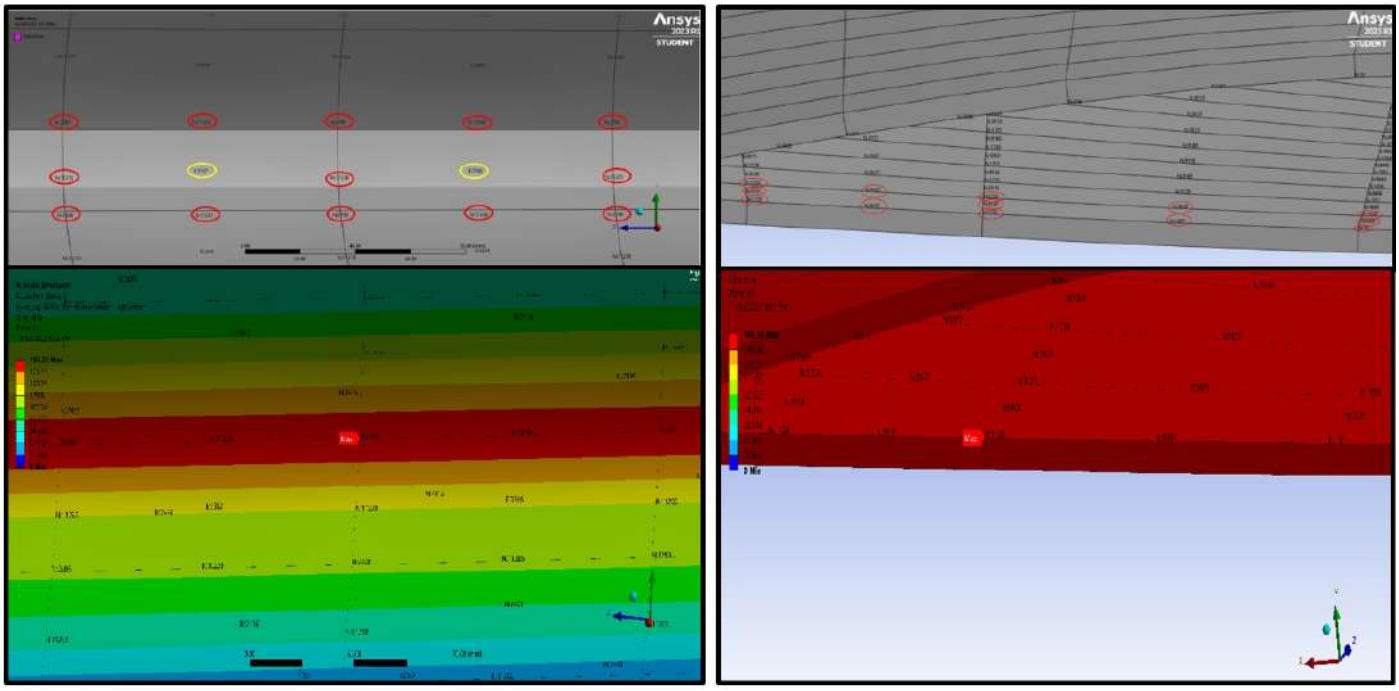
Figure 18: Total strain energy distribution of glass polyester.



Source: Authors.

The maximum strain energy is 40.823 J at element no. 3367 and the total strain energy is 8221.9 J. Max. stress occurs at node no. 2799 & max. deformation occurs at node no. 1728. The elements and their corresponding nodes are marked in the figure 19 which were taken for nodal analysis. For each element, nodes were taken anti-clockwise and started from the bottom left node, as shown in Table 10.

Figure 19: a) Von-Mises stress distribution to the corresponding nodes (Element No. 3366 & 3367); b) Total deformation to corresponding nodes (Element No. 3980 & 4102).



Source: Authors.

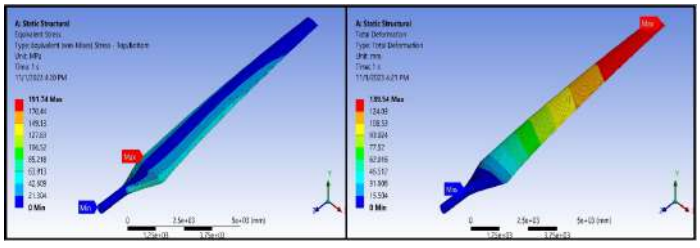
Table 10: Element no. and corresponding node no. at the most vulnerable region of glass polyester.

Element	Nodes							
3366	2798	11206	2790	11205	2791	11208	2799	11220
3367	2806	11221	2798	11220	2799	11223	2807	11235
3980	1728	5657	19	5658	1858	9189	1723	9188
4102	1729	9197	1728	9188	1723	9187	1724	9191

Source: Authors.

8.7.3. Epoxy E-glass UD.

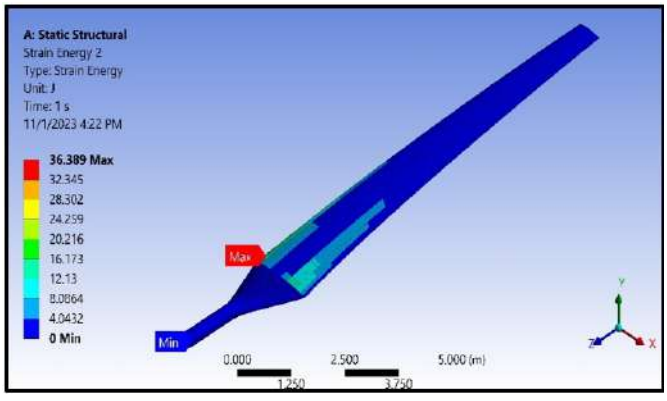
Figure 20: Total deformation and von-Mises stress distribution of epoxy E-glass UD.



Source: Authors.

The maximum deformation is 139.54 mm, and it occurs at the tip of the blade. The maximum von-Mises stress is 191.74 MPa. Two elements were taken around the node of maximum deformation (Element no 3980 & 4102) and maximum stress (Element no. 3366 & 3367).

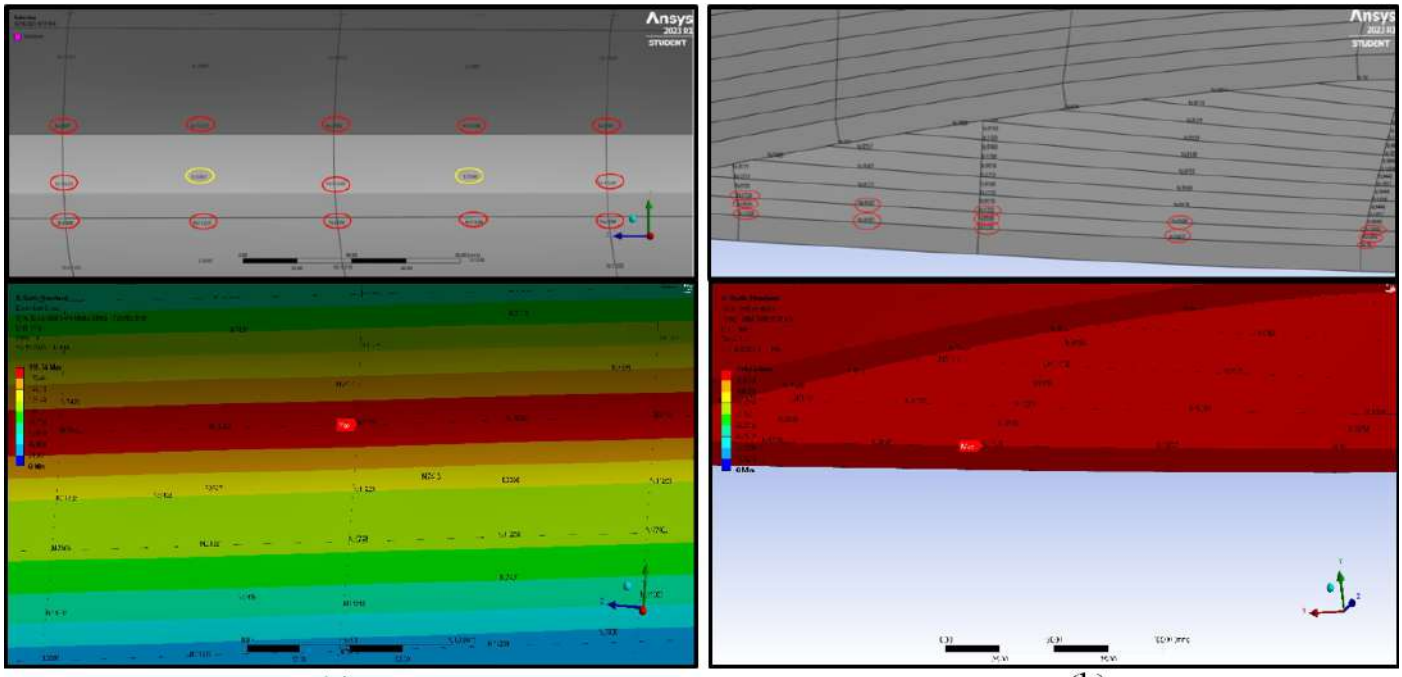
Figure 21: Total strain energy distribution of epoxy E-glass UD.



Source: Authors.

The maximum Strain Energy is 36.389 J at element no. 3367 and the total strain energy is 6955.6 J. Max. stress occurs at node no. 2799 & max. deformation occurs at node no. 1728. The elements and their corresponding nodes are marked in Fig. 22, which were taken for nodal analysis. For each element, nodes were taken anti-clockwise and started from the bottom left node, as shown in Table 11.

Figure 22: a) Von-Mises stress distribution to the corresponding nodes (Element No. 3366 & 3367); b) Total deformation to corresponding nodes (Element No. 3980 & 4102).



Source: Authors.

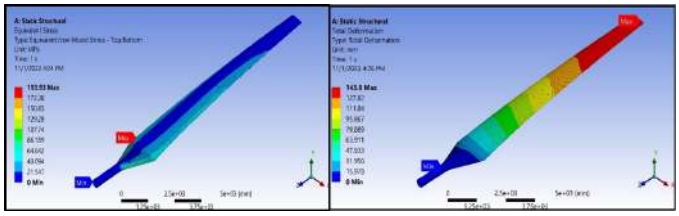
Table 11: Element no. and corresponding node no. at the most vulnerable region of epoxy E-glass UD.

Element	Nodes							
3366	2798	11206	2790	11205	2791	11208	2799	11220
3367	2806	11221	2798	11220	2799	11223	2807	11235
3980	1728	5657	19	5658	1858	9189	1723	9188
4102	1729	9197	1728	9188	1723	9187	1724	9191

Source: Authors.

8.7.4. Epoxy S-glass UD.

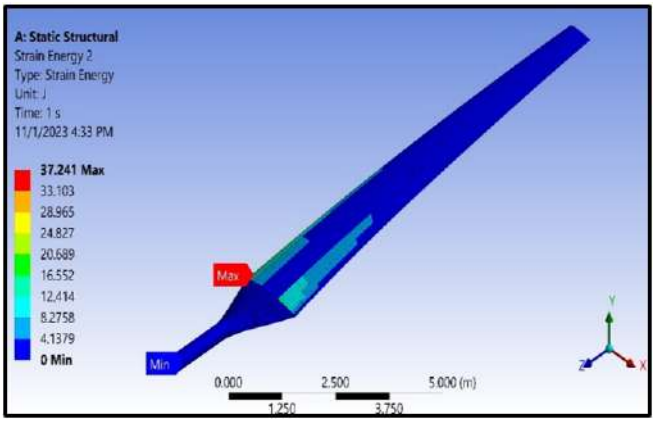
Figure 23: Total deformation and von-Mises stress distribution of epoxy S-glass UD.



Source: Authors.

The maximum deformation is 143.8 mm, and it occurs at the tip of the blade. The maximum von-Mises stress is 193.93 MPa. Two elements were taken around the node of maximum deformation (Element no 3980 & 4102) and maximum stress (Element no. 3366 & 3367).

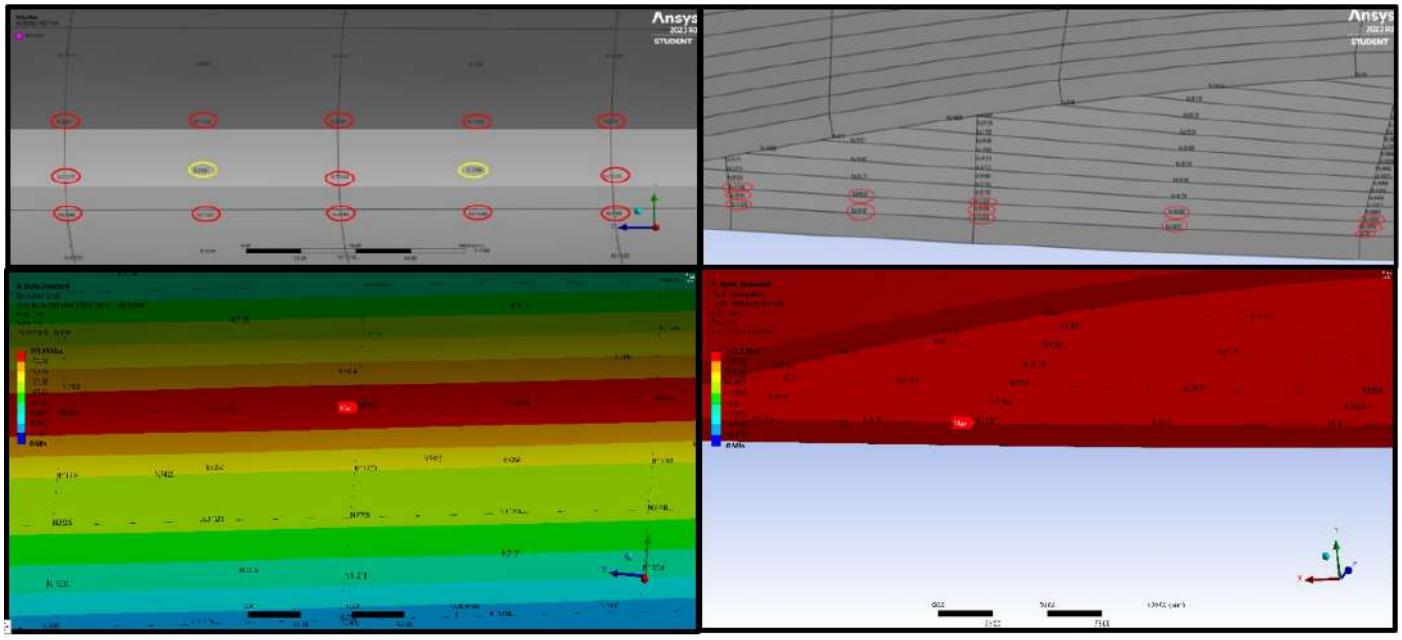
Figure 24: Total strain energy distribution of epoxy S-glass UD.



Source: Authors.

The maximum strain energy is 37.241 J at element no. 3367 and the total strain energy is 7137.9 J. Max. stress occurs at node no. 2799 & max. deformation occurs at node no. 1728. The elements and their corresponding nodes are marked in Fig. 25, which were taken for nodal analysis. For each element, nodes were taken anti-clockwise and started from the bottom left node, as shown in Table 12.

Figure 25: a) Von-Mises stress distribution to the corresponding nodes (Element No. 3366 & 3367); (b) Total deformation to corresponding nodes (Element No. 3980 & 4102).



Source: Authors.

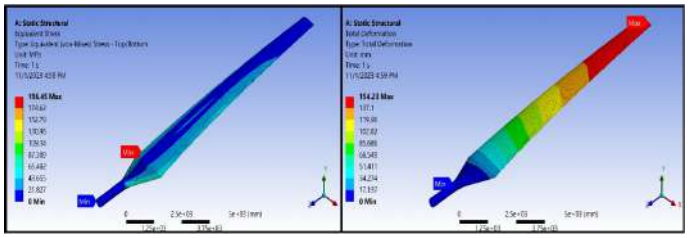
Table 12: Element no. and corresponding node no. at the most vulnerable region of epoxy S-glass UD.

Element	Nodes							
3366	2798	11206	2790	11205	2791	11208	2799	11220
3367	2806	11221	2798	11220	2799	11223	2807	11235
3980	1728	5657	19	5658	1858	9189	1723	9188
4102	1729	9197	1728	9188	1723	9187	1724	9191

Source: Authors.

8.7.5. Epoxy carbon UD (230 GPa) prepreg.

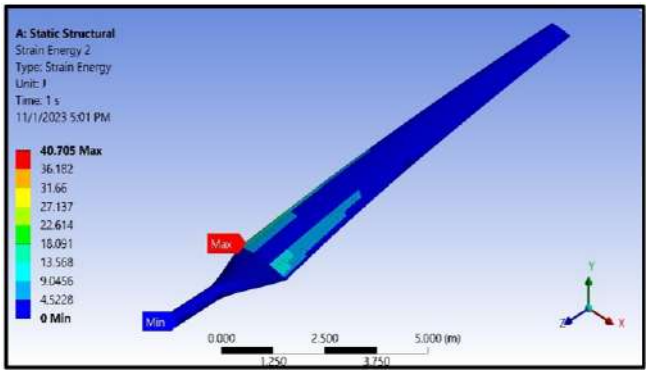
Figure 26: Total deformation and von-Mises stress distribution of epoxy carbon UD (230 GPa) prepreg.



Source: Authors.

The maximum deformation is 154.23 mm, and it occurs at the tip of the blade. The maximum von-Mises stress is 196.45 MPa. Two elements were taken around the node of maximum deformation (Element no 3980 & 4102) and maximum stress (Element no. 3366 & 3367).

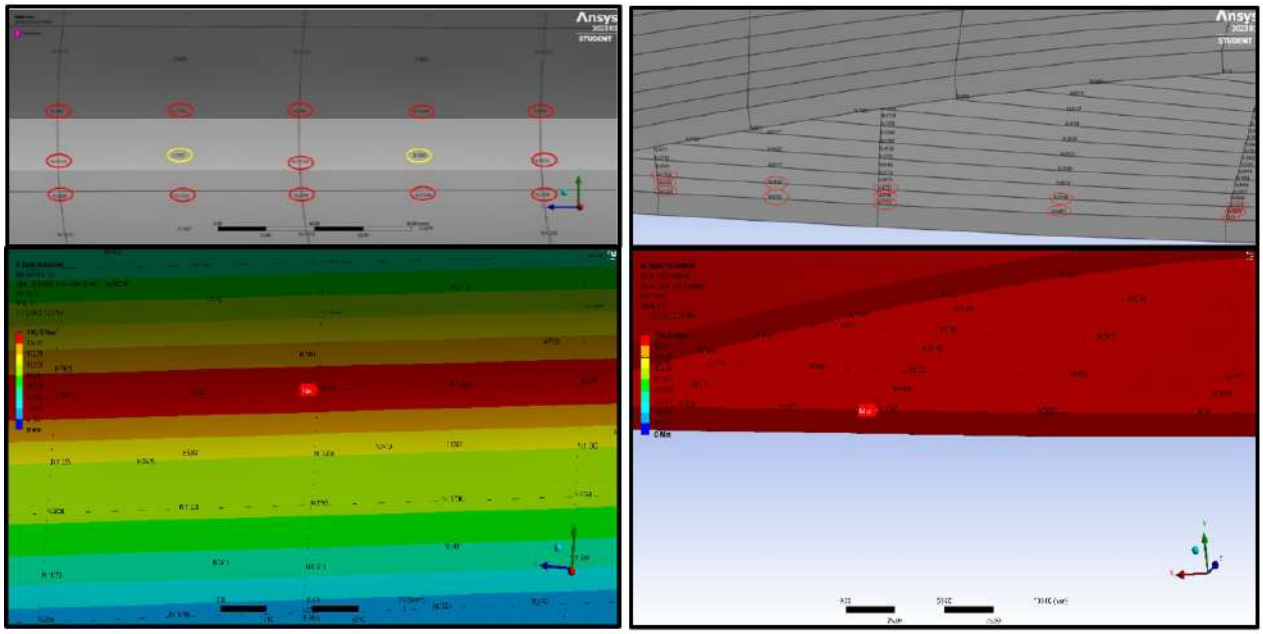
Figure 27: Total strain energy distribution of epoxy carbon UD (230 GPa) prepreg.



Source: Authors.

The maximum strain energy is 40.705 J at element no. 3367 and the total strain energy is 7644.7 J. Max. stress occurs at node no. 2799 & max. deformation occurs at node no. 1728. The elements and their corresponding nodes are marked in Fig. 28, which were taken for nodal analysis. For each element, nodes were taken anti-clockwise and started from the bottom left node, as shown in Table 13.

Figure 28: a) Von-Mises stress distribution to the corresponding nodes (Element No. 3366 & 3367); (b) Total deformation to corresponding nodes (Element No. 3980 & 4102).



(a) (b)

Source: Authors.

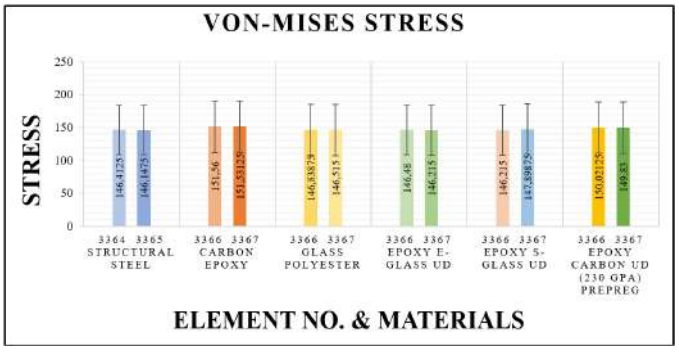
Table 13: Element no. and corresponding node no. at the most vulnerable region of epoxy carbon UD (230 GPa) prepreg.

Element	Nodes							
3366	2798	11206	2790	11205	2791	11208	2799	11220
3367	2806	11221	2798	11220	2799	11223	2807	11235
3980	1728	5657	19	5658	1858	9189	1723	9188
4102	1729	9197	1728	9188	1723	9187	1724	9191

Source: Authors.

8.8. Graphical Analysis.

Figure 29: Comparison graph for average Von-Mises stress with standard deviation for the targeted elements of corresponding material.

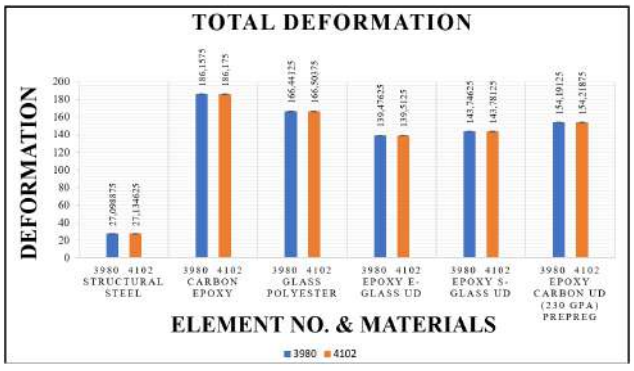


Source: Authors.

Graphical and tabular representation of the results are provided for the targeted elements of corresponding material, along with the average value of the outcome and their respective standard deviations. The outcomes are also compared for maximum von-Mises stress, maximum deformation, and total strain energy of different materials.

The two elements where maximum Von-Mises stress and maximum deformation occur are selected and the average stress of these elements for the corresponding material is plotted in Fig. 29 and the average deformation is plotted in Fig. 30. These figures are also accompanied by standard deviation. The average stress and the average deformation are found by taking the mean of stress and deformation found in the eight nodes respectively from analysis for corresponding elements of different materials.

Figure 30: Comparison graph for average deformation with standard deviation for the targeted elements of corresponding material.



Source: Authors.

The values of average stress and average deformation for each element for corresponding materials and also the standard deviation for the corresponding outcomes is also tabulated in Table 14 and Table 15 giving a brief idea of how the outcome varies for different materials.

Table 14: Comparison of average stress and standard deviation of corresponding materials at their targeted elements.

Materials	Elements	Average stress (MPa)	Standard deviation (MPa)
Structural Steel	3364	146.41	37.21
	3365	146.14	37.38
Carbon Epoxy	3366	151.56	39.13
	3367	151.53	39.37
Glass Polyester	3366	146.84	38.89
	3367	146.52	39.07
Epoxy E-Glass UD	3366	146.48	37.83
	3367	146.22	38.01
Epoxy S-Glass UD	3366	148.15	38.26
	3367	147.89	38.44
Epoxy Carbon UD (230 GPa) Prepreg	3366	150.02	38.76
	3367	149.83	38.97

Source: Authors.

Table 15: Comparison of average deformation and standard deviation of corresponding materials at their targeted elements.

Materials	Elements	Average deformation (mm)	Standard deviation (mm)
Structural Steel	3980	27.09	0.06
	4102	27.13	0.02
Carbon Epoxy	3980	186.15	0.03
	4102	186.17	0.01
Glass Polyester	3980	166.44	0.11
	4102	166.50	0.03
Epoxy E-Glass UD	3980	139.47	0.06
	4102	139.51	0.02
Epoxy S-Glass UD	3980	143.74	0.05
	4102	143.78	0.01
Epoxy Carbon UD (230 GPa) Prepreg	3980	154.19	0.04
	4102	154.21	0.01

Source: Authors.

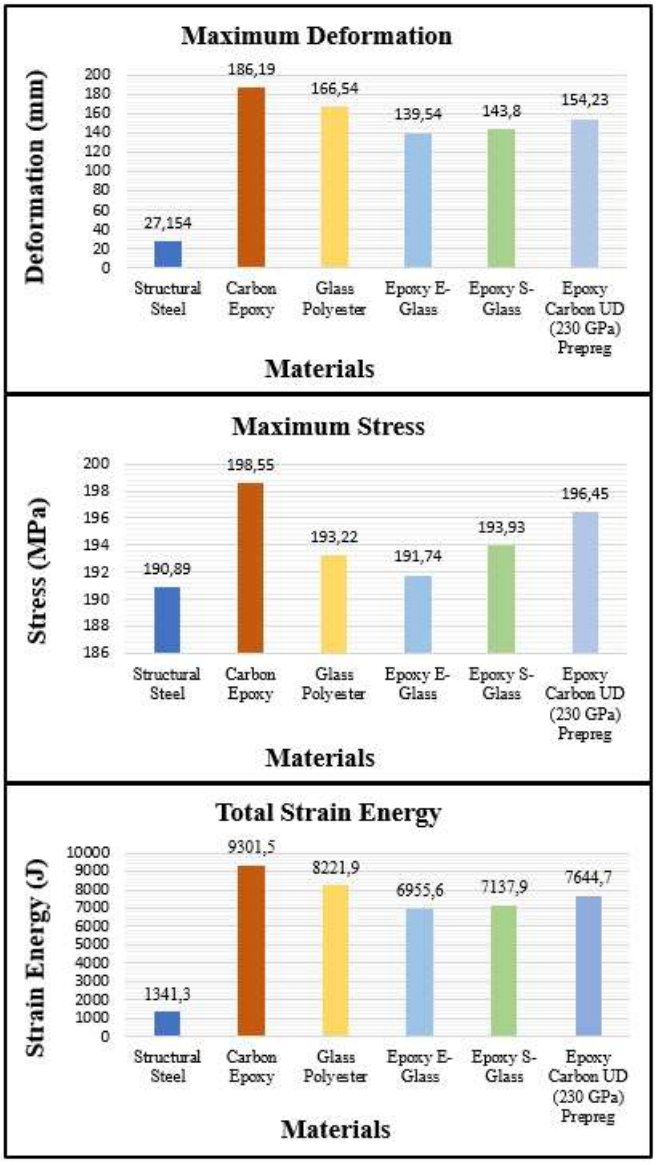
Table 16: Comparison of maximum von-Mises stress, maximum deformation & total strain energy for different composite materials.

Materials	Maximum von-Mises stress (MPa)	Maximum deformation (mm)	Total strain energy (J)
Structural Steel	190.89	27.154	1341.3
Carbon Epoxy	198.55	186.19	9301.5
Glass Polyester	193.22	166.54	8221.9
Epoxy E-Glass UD	191.74	139.54	6955.6
Epoxy S-Glass UD	193.93	143.8	7137.9
Epoxy Carbon UD (230 GPa) Prepreg	196.45	154.23	7644.7

Source: Authors.

The maximum Von-Mises stress, maximum deformation and total strain energy are tabulated in table 16 for each material. Also, the results graphically represented in figure 31 to obtain a more vivid outcome.

Figure 31: Comparison of maximum deformation, maximum stress, and total strain energy for different composite materials.



Source: Authors.

The graphical representation shows a more effective comparison between the materials. The maximum deformation and stress occur in Carbon Epoxy and the total strain energy is also maximum for this material. The minimum of these three occur in the case of structural steel. The optimum material requires a balance between these three characteristics.Analysis of turbine blade using composite materials also explored by Mathew et al. [8], Appadurai and Irudaya [15] and Diaaeldin et al. [16].

In [8] analysis on wind turbine blade is done using composite materials including Structural steel, E-glass, S-glass, Aluminum alloy and Epoxy-carbon considering isotropic properties. That is, they considered directional independence. In comparison, this study considers orthotropic properties of the used composite materials. Because composite materials show variation in their structural properties according to axial orientation.

In [15] analysis is done using carbon epoxy, graphite composite and steel varying impacted loads throughout the blade. In comparison, in this study load is applied segmenting the blade edge wise and flap wise for more accurate analysis.

In [16] six composite materials are implemented, and analysis results is concluded considering total deformation, Young's Modulus along axial direction and von-mises stress. While this study focuses on strain energy distribution along with other properties.

Now for this study, rather than using the whole blade geometry for analyzing different properties, nodal analysis is conducted. Most load impacted elements are taken and their nodal values for Deformation, Von-mises stress distribution is recorded. Then the analysis is taken one step further considering the Strain energy distribution along the blade as well. This micro level analysis as well as energy distribution will further be helpful in mesh convergence and reinforcing materials according to extremely affected zones.

The turbine blade used in this study is an existing one described in [8], so the analysis results follow the same trend in most cases as this study. Most importantly, this work has been able to show better deformation results using orthotropic analysis and considering strain energy for composite materials. Also, by segmenting the loading on flap wise and edge wise the result accuracy is increased.

Conclusions

An in-depth assessment was conducted using Ansys FEA to analyze the deformation, von-Mises stress, and maximum strain energy across five distinct composite materials in comparison to conventional structural steel.

For the conventional structural steel, the deformation and von-Mises stress is well acceptable whereas the strain energy is lesser compared to other materials. Glass Polyester, Epoxy E-Glass UD and Epoxy S-Glass UD shows approximately similar results in terms of von-Mises stress but Glass Polyester shows superiority in terms of strain energy where as in terms of deformation Epoxy E-Glass UD shows better result. But glass polyester shows relatively larger deformation. Except for carbon epoxy, the other materials exhibited relatively similar von-Mises stress values. Carbon epoxy has the largest total strain energy but also has the largest deformation and relatively large von-Mises stress which is not desirable. Epoxy Carbon UD (230 GPa) Prepreg shows better result than glass polyester in terms of deformation but has comparatively less strain energy than glass polyester.

Considering all three critical aspects—von-Mises stress, maximum deformation, and strain energy, it becomes apparent that Epoxy E-glass UD, Epoxy S-Glass UD and Epoxy Carbon UD (230 GPa) Prepreg have relatively balanced characteristics. Further research scope can be done considering a combination of these composite materials to find a much more optimum result of these three characteristics. Twist angle of the blade can also be introduced in the future study.

References.

[1] Rajveer Mittal, K.S.Sandhu and D.K.Jain, "An Overview of Some Important Issues Related to Wind Energy Conversion System (WECS)," International Journal of Environmental Science and Development, vol. 1, no. 4, pp. 351-363, October 2010.

[2] M. Jureczko, M. Pawlak and A. Mężyk, "Optimisation of wind turbine blades," Journal of Materials Processing Technology, vol. 167, no. 2-3, pp. 463-471, 2005.

[3] Asis Sarkar and Dhiren Kumar Behera, "Wind Turbine Blade Efficiency and Power Calculation with Electrical Analogy," International Journal of Scientific and Research Publications, vol. 2, no. 2, pp. 232-236, February 2012.

[4] Ole Thybo Thomsen, "Sandwich Materials for Wind Turbine Blades – Present and Future," Journal of Sandwich Structures and Materials, vol. 11, no. 1, pp. 7-26, January 2009.

[5] Meng-Kao Yeh and Chen-Hsu Wang, "Stress analysis of composite wind turbine blade by finite," in IOP Conference Series: Materials Science and Engineering, Tokyo, 2017.

[6] C. Kong, J. Bang and Y. Sugiyama, "Structural investigation of composite wind turbine blade considering various load cases and fatigue life," Energy, vol. 30, no. 11-12, pp. 2101-2114, 2005.

[7] M. E. Bechly and P. D. Clausent, "Structural Design of a Composite Wind Turbine Blade Using Finite Element Analysis," Computers & Structures, vol. 63, no. 3, pp. 639-646, May 1997.

[8] Akhil P Mathew, Athul S, Barath P and Rakesh S, "Structural Analysis of Composite Wind Turbine Blade" International Research Journal of Engineering and Technology (IRJET), vol. 05, no. 06, pp. 1377-1388, June 2018.

[9] Tri-Dung Ngo, Composite and Nanocomposite Materials: From Knowledge to Industrial Applications, London: IntechOpen, 2020.

[10] Rahul Reddy Nagavally, "Composite Materials - History, Types, Fabrication Techniques, Advantages, And Applications," in Proceedings of 29th IRF International Conference, India, 2016.

[11] Darshil U. Shah, "Natural fibre composites: Comprehensive Ashby-type materials selection charts," Materials and Design, vol. 62, pp. 21-31, October 2014.

[12] Sarah David Müzel, Eduardo Pires Bonhin, Nara Miranda Guimarães and Erick Siqueira Guidi, "Application of the Finite Element Method in the Analysis of Composite Materials: A Review," Polymers, vol. 12, no. 4, p. 818, April 2020.

[13] P. D. E. a. t. F. E. Method, Pavel Ŝolín, Canada: Wiley, 2005.

[14] Amna Algolfat, Weizhuo Wang and Alhussein Albarbar, "Dynamic Response Analysis of A 5 MW NREL Wind Turbine Blade under Flap-Wise and Edge-Wise Vibrations," Journal of Dynamics, Monitoring and Diagnostics, vol. 1, no. 4, pp. 208-222, September 2022.

[15] M. Appadurai and E. Fantin Irudaya, "Finite Element Analysis of Composite Wind Turbine," in International Conference on Electrical Energy Systems (ICEES), Chennai, 2021.

[16] Diaaeldin M. Elsherif, Ayman A. Abd El-Wahab, Ramadan Badawy Mohamed Elgamsy and Mohamed Hazem Abdellatif, ”Material Selection Of Wind Turbine Blade Using Finite Element Method,”International Journal of Scientific & Technology Research, vol. 8, no. 01, pp. 22-32, January 2019.

[17] Irshadhussain I. Master, Azim Aijaz Mohammad and Ratnesh T. Parmar, ”Aerodynamic Performance Evaluation of a Wind Turbine Blade by Computational and Experimental Method,” International Journal of Engineering Research & Technology (IJERT), vol. 3, no. 6, pp. 73-81, June 2014.

[18] S. K. Mutkule, P. P. Gorad, S. R. Raut and A. H. Nikam, ”Optimum and Reliable Material for Wind Turbine,” International Journal of Engineering Research & Technology (IJERT), vol. 4, no. 02, pp. 624-627, February 2015.

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 240–250

ISSN: 1697-4840, www.jmr.unican.es

Transport of Electric and Hybrid Vehicles on Board Ships: Risks and Measures to Consider for a Growing Problem

J.A. González Almeida[1,*], F.H. Hoyos Medina[1], M.C. Adrián de Ganzo[1], A.U. Gómez Correa[1], J. Almenar de Luz[2]

ARTICLE INFO

Article history:
Received 10 Oct 2023;
in revised from 11 Oct 2023;
accepted 21 Nov 2023.

Keywords:
fire prevention, EV, PHEV, fire risk, maritime transport.

ABSTRACT

The transport of electric and hybrid vehicles on passenger ships presents a risk of fire, mainly due to the lithium batteries that power these vehicles. This risk has been evident in several incidents, leading to concern and safety measures by shipping companies. Although there are no specific regulations for the transport of electric vehicles on ships, efforts are being made to develop safe systems for their transport and to adjust international maritime regulations to this new scenario. The International Maritime Organisation has acknowledged the risk of fire on ships carrying electric vehicles and has urged the implementation of safety protocols to reduce this risk. Some shipping lines have banned or restricted the embarkation of these vehicles on their vessels, while others have implemented specific measures, such as the acquisition of fire extinguishing equipment and the training of personnel in extinguishing fires on electric vehicles. In summary, the risk of electric and hybrid vehicle fires on passenger ships is a growing concern that requires the implementation of specific safety measures.

1. Introduction.

Mobility in the 21st century is being transformed by the need to adopt more sustainable forms of transport. In this scenario, electric vehicles (EVs) and hybrids are taking a central role in the automotive industry [1]. These vehicles share key features and technologies that make them promising for a cleaner and more efficient future. With the integration of advanced batteries, innovative propulsion systems and environmental policy support, EVs and hybrids are leading the way towards more sustainable mobility [2].

Electric vehicles (EVs) and hybrids share some similarities, such as the use of electric technology to improve fuel efficiency and reduce emissions. However, they have key differences [3]. EVs run exclusively on electricity, stored in batteries and used to power an electric motor. They have no internal combustion engine and require charging stations. Hybrids, on the other hand, combine an internal combustion engine with an electric motor, allowing them to use both fuel and electricity. Hybrids can be recharged while driving and are not completely dependent on charging stations. These characteristics define their respective benefits and limitations in terms of performance, cost and environmental sustainability. Both types of vehicles rely on advanced rechargeable batteries, usually lithium-ion, to store and supply energy. Although batteries in electric vehicles tend to be larger, those in hybrids also play a crucial role in backing up the internal combustion engine and providing electric assistance under certain conditions [4].

Another point of convergence is the use of regenerative braking. Both types of vehicles incorporate systems that convert the kinetic energy generated during braking and deceleration into electrical energy, thus recharging the batteries. This innovation not only improves efficiency, but also extends the range of the vehicles [5].

Both electric and hybrid vehicles face the common challenge of charging infrastructure. The expansion of fast and accessible charging stations is critical to the success of both, and governments and businesses are working to develop a network

[1]Departamento de Ingeniería Civil, Náutica y Marítima. Universidad de La Laguna.
[2]Fred Olsen Express.
[*]Corresponding author: J.A. González-Almeida. E-mail Address: jagonal@ull.edu.es.

that supports the growing adoption of these vehicles [6].

Safety is a priority in the design of electric and hybrid vehicles. Both types must comply with strict safety regulations and standards, from crash tests to specific protocols for battery thermal management. Training of emergency services also plays a crucial role in ensuring effective responses in case of accidents [7].

2. Background.

2.1. The Growth of Electric and Hybrid Vehicles: A Global Analysis.

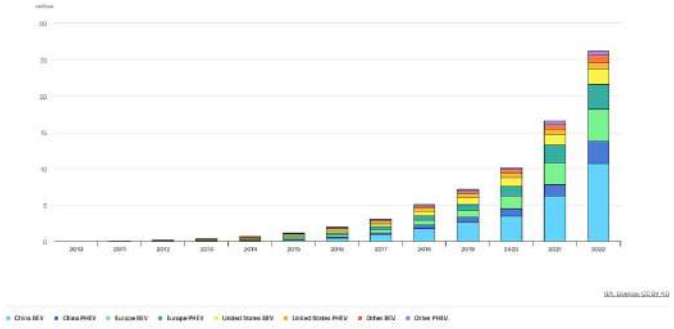
The demand for electric vehicles (EVs) and hybrids worldwide has experienced significant growth in recent years, driven by growing environmental awareness and the implementation of sustainability and environmental protection policies in several countries [8].

2.1.1. Global Market Development.

According to a report by EY, by 2022, the electric vehicle (EV) market will grow by 55%, accounting for 13% of total global vehicle sales, with 10.5 million units sold [9]. This growth has occurred against a backdrop of supply chain disruptions and rising commodity prices, highlighting the robustness of the EV market.

China has emerged as a leader in hybrid electric vehicle production and demand. In October 2022, the wholesale volume of New Energy Vehicle (NEV) passenger cars in China increased by 85.8% year-on-year, with a notable increase in sales of battery electric vehicles (BEVs) and plug-in hybrids (PHEVs) [10].

Figure 1: IEA, Global electric car stock, 2010-2022.



Source: IEA, Paris https://www.iea.org/data-and-statistics/charts/global-electric-car-stock-2010-2022, IEA. Licence: CC BY 4.0.

By the end of 2020, there were 10 million electric cars registered worldwide, with Europe overtaking China as the world's largest EV market, driven in part by proactive government policies [11].

2.1.2. Sustainability Policy and its Impact.

Sustainability policies have played a crucial role in the growth of the EV market. By 2021, global electric car sales will double to a record 6.6 million, driven by continued government policy support and increased public spending on subsidies and incentives [12].

However, the sector faces challenges, including high prices of critical minerals for battery manufacturing and disruptions in the supply chain. In the long term, a concerted effort is required to develop adequate charging infrastructure for electric vehicles [13].

2.1.3. Key Issues in the Growing Demand for Electric Vehicles Worldwide.

Factors such as improved engine performance and fuel efficiency are making EVs more attractive to consumers [14]. In addition, growing environmental awareness and preference for cleaner technologies are driving demand [15]. Another crucial factor is the combination of high fuel prices, lower EV prices, tax incentives and the elimination of charging concerns [16].

The following highlights some of the key aspects that have contributed to the growing demand for electric vehicles worldwide:

- Environmental Awareness: Growing awareness of the environmental impacts of fossil fuel-based transport has led to an increased preference for cleaner, more sustainable vehicles.
- Technological Advances: Continued improvements in battery technology and the expansion of charging infrastructure have increased the attractiveness of electric vehicles, overcoming previous technological barriers.
- Government Incentives: Many governments have implemented tax incentives, subsidies and support policies to encourage the adoption of electric vehicles, making it more attractive to consumers.
- Environmental Regulations: Stricter emissions regulations and pressure to meet climate targets have led automakers to invest in electric vehicles to meet more stringent environmental standards.
- Model Variety: Diversification in electric vehicle model offerings by manufacturers has given consumers more choice, from compact cars to SUVs and luxury vehicles.
- Economy of Scale: As production of electric vehicles has increased, economies of scale have enabled reductions in manufacturing costs, making these vehicles more affordable.
- Consumer Awareness: The shift in consumer perception towards sustainable mobility has been an important driver, with more people recognising the environmental and economic benefits of electric vehicles.

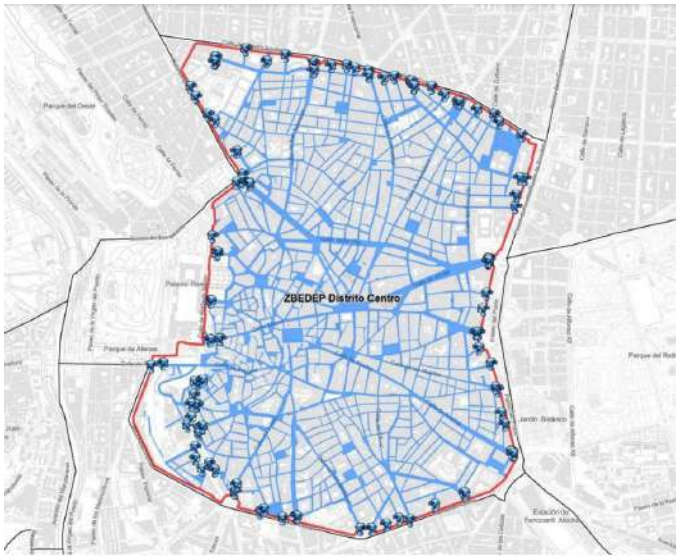
- Corporate Commitments: Many companies, both automotive and non-automotive, have made commitments to sustainability and fleet electrification, contributing to the growing demand for electric vehicles.
- Charging Infrastructure: The expansion of charging infrastructure, including fast chargers and public charging networks, has addressed range concerns and facilitated the adoption of electric vehicles.
- Continued Innovation: Continued innovation in electric vehicle design, performance and features has generated renewed interest and attracted consumers seeking modern driving experiences.

But all this would not be enough if governments did not implement measures to reduce environmental pollution and tacitly prohibit the access of vehicles with combustion engines to city centres. In large cities, this implies the approval of regulations for the implementation of low-emission zones, encouraging the replacement of the current vehicle fleet with non-polluting vehicles.

2.2. *Low-emission zones in cities.*

Low Emission Zones (LEZs) have emerged as a key response to environmental and air quality challenges in urban settings. These areas, present in cities around the world, are designed to reduce vehicle emissions and promote more sustainable modes of transport [17].

Figure 2: EPZ Madrid.



Source: neomotor.epe.es.

The EPZs are geographical areas within a city where specific restrictions or requirements on emissions produced by vehicles circulating in them are applied. The main objective is to improve air quality by reducing pollution and encouraging the use of cleaner vehicles [18].

The implementation of these low emission zones aims to achieve a number of environmental objectives [19]:

- Improved Air Quality: The reduction of emissions directly contributes to an improvement in air quality, benefiting the health of residents.
- Promotion of Sustainable Transport Modes: EPZs encourage the use of more sustainable modes of transport, such as walking, cycling and public transport.
- Environmental Compliance: They help cities comply with environmental regulations and achieve emission reduction targets.

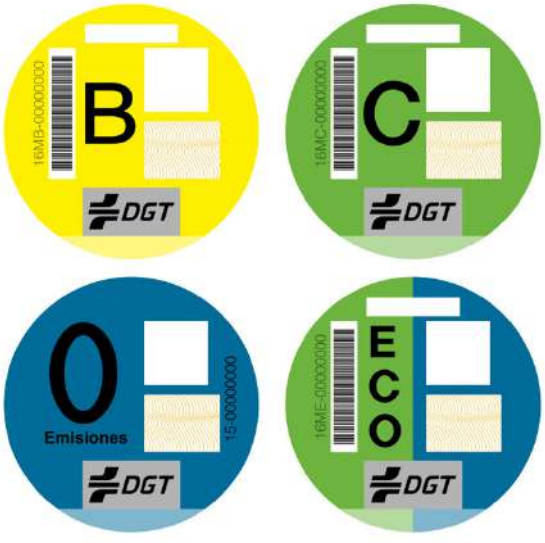
Some key issues about these types of areas within cities are, for example:

- Access Restrictions: EPZs often limit access for vehicles that are highly polluting or do not meet specific emission standards [20].
- Environmental Regulations: These set emission standards that vehicles must meet in order to enter the zone, encouraging the adoption of cleaner technologies [21].
- Incentives for Clean Vehicles: Incentives, such as fee waivers or free parking, are offered to owners of low-emission vehicles [22].

But of course there must be a series of control measures in place to ensure compliance with the rules related to these zones, currently the control of vehicles accessing these zones is mainly based on two formats:

- Vehicle Tagging Systems [23]: Many cities implement vehicle labelling systems that classify vehicles according to their emissions, facilitating identification and compliance.

Figure 3: Environmental vehicle markings in Spain.



Source: industriassaludes.es.

- Access Control Technology: Technologies such as cameras and control systems are used to monitor traffic and ensure compliance with access restrictions.

Figure 4: Barcelona City Hall traffic control room.

Source: LaSexta.es.

In general, both measures are usually implemented at the same time and, more importantly, non-compliance with the measures can lead to a penalty system, which means that the former users of these zones will gradually have to adapt not only to the new regulations but also to change their traditional combustion vehicles for vehicles that comply with the emission reduction regulations, which means a significant investment for them. In the case of Spain, in order to promote compliance with European guidelines for reducing air pollution, in 2019 the MOVES Plan (Plan de Movilidad Eficiente y Sostenible) was approved, a Spanish government initiative designed to promote sustainable mobility. This plan is part of the measures promoted by the government to reduce CO2 emissions and other polluting gases, in line with the European Union's objectives on climate change and energy transition.

The Moves Plan (currently in its third edition), basically consists of the implementation of the following measures [24]:

- Incentives for the Purchase of Electric Vehicles: MOVES Plan offers financial aid for the purchase of electric, plug-in hybrid and fuel cell vehicles. These incentives are aimed at individuals, companies and public entities.

- Charging Infrastructure: This includes aid for the installation of charging points for electric vehicles, both in public spaces and in private homes and companies.

- Electric Bicycle Lending Systems: Promotes sustainable mobility through the promotion of electric bicycle systems, especially in urban areas.

- Sustainable Mobility Measures in Companies: Encourages the implementation of transport plans for employees in companies, seeking to reduce the use of private vehicles and promote more sustainable alternatives.

The MOVES Plan is part of the Spanish government's energy transition policies and is aligned with European Union guidelines on reducing emissions and promoting renewable energies. Although it is a state plan, its management and implementation is decentralised to the autonomous communities, which adapt the plan to their specific needs and particularities.

The MOVES Plan is financed by state funds, often complemented by European funds earmarked for energy transition and the fight against climate change, and each new edition of the MOVES Plan may bring changes in the conditions, requirements and amounts of aid, so it is important to consult the most recent call for proposals for updated information.

2.3. Risk of Fire in Electric (EV) and Hybrid (PHEV) Vehicles.

Transition towards more sustainable vehicles, such as electric and hybrid vehicles, has raised safety concerns, specifically in relation to the risk of fire. Although these vehicles are designed with advanced technologies to minimise risks, it is imperative to explore this aspect in depth and understand the safety measures implemented. In recent years, all major car brands have been including hybrid or pure electric vehicles in their portfolio in response to the demand being experienced.

Factors contributing to the risk of fire include:

- Lithium-ion batteries: Both electric and hybrid vehicles rely on lithium-ion batteries. While energy efficient, these batteries can generate heat, posing a potential fire risk in extreme situations.

- Physical Damage: Severe impacts or significant physical damage can increase the risk of fires, especially in severe traffic accident situations that compromise the integrity of the battery.

- Charging Problems: Charging-related problems, such as overcharging or the use of unauthorised chargers, can contribute to the risk of fire by adversely affecting the thermal management of the battery.

To avoid these risks, manufacturers have implemented a number of safety measures:

- Battery Management Systems: Both types of vehicles are equipped with advanced battery management systems to monitor temperature and prevent hazardous situations.

- Automatic Disconnection: In the event of an accident, many electric vehicles are designed to automatically disconnect battery power, reducing the possibility of fires.

- Stringent Regulations and Standards: Industry and regulatory bodies set strict regulations and standards for the safety of electric and hybrid vehicles, including crash testing and specific protocols for battery safety.

- Technological Innovations: Ongoing research and technological innovations seek to improve battery safety, introducing fire extinguishing systems and safer materials.

- Specialised Training: Emergency services receive specialised training to deal with situations involving electric and hybrid vehicles, ensuring effective and safe responses.

Recent studies have found that the risk of fires in this type of vehicle is no higher than in traditional combustion vehicles [25].

3. Development & Discussion.

3.1. Worldwide transport of vehicles by ship.

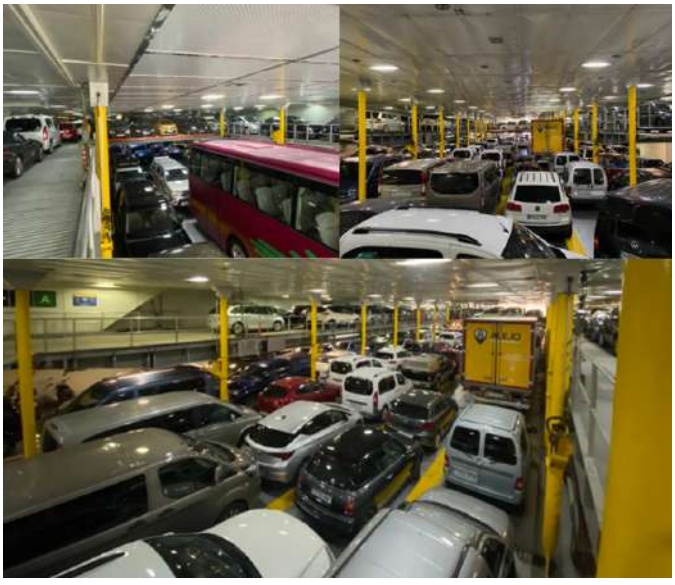
Transporting vehicles by ship worldwide is a complex process that involves various stages, each requiring meticulous planning and coordination [26]. The process can be broadly divided into several key steps:

Preparation and Planning: Before vehicles are transported, there's a need for thorough planning. This includes route planning, considering factors like weather conditions, sea routes, and political situations in different regions. For instance, longer routes might be chosen to avoid areas with piracy risks [27].

Vehicle Logistics and Consolidation: Vehicles are often transported from manufacturing facilities to a consolidation center near the port. Here, they are prepared for shipping, which includes ensuring they are in a drivable condition, disabling alarms, and sometimes partially draining fuel.

Loading onto the Ship: Vehicles are driven onto the ship using their own power. This process is known as "roll-on." The ships used are often specialized Ro-Ro (Roll-on/Roll-off) vessels designed for transporting wheeled cargo. The vehicles are then securely fastened to the deck to prevent movement during transit [28].

Figure 5: Inside Ro-Ro ship in Spain.



Source: Authors.

Maritime Transit: During the sea voyage, the primary concern is the safety and security of the cargo. The ships are equipped with stabilization systems to minimize the effect of rough seas. The route and speed are constantly adjusted to avoid bad weather and ensure timely delivery [29].

Unloading and Distribution: Upon reaching the destination port, the vehicles are driven off the ship, a process known as "roll-off." They are then moved to a holding area where they undergo customs and regulatory checks before being distributed to dealers or end customers.

Regulatory Compliance: International shipping of vehicles involves compliance with various regulations. This includes customs laws, environmental regulations (like the International Maritime Organization's regulations on emissions), and safety standards [30].

Insurance and Risk Management: Transporting vehicles by sea carries risks like damage due to weather, accidents, or piracy. Therefore, insurance is a critical aspect, covering potential damages or losses during transit [31].

Technological Integration: The use of technology in tracking and managing the logistics is vital. GPS tracking, RFID tags, and other technologies enable real-time tracking of the vehicles throughout the journey [32].

Environmental Considerations: The shipping industry is increasingly focusing on reducing its environmental impact. This includes using ships with lower emissions, optimizing routes for fuel efficiency, and exploring alternative fuels [33].

3.2. Transport of vehicles on board ships in Spain.

Transporting vehicles by ship in Spain is a specialized segment of the maritime logistics industry, reflecting the country's position as both a significant automotive manufacturer and a hub in Mediterranean and Atlantic shipping routes [34]. Here's a detailed overview:

- Key Ports and Infrastructure: Spain's main ports for vehicle shipping are Barcelona, Valencia, and Bilbao. These ports have specialized infrastructure, including large Ro-Ro (Roll-on/Roll-off) terminals, to facilitate the efficient loading and unloading of vehicles [35].

- Automotive Industry Integration: Spain is home to several major automobile manufacturing plants, including those of SEAT, Volkswagen, and Ford. The proximity of these plants to ports like Barcelona and Valencia facilitates efficient transport logistics. Vehicles are often transported from the factory to the port via short road trips or rail [36].

- Loading and Shipping Procedures: The Ro-Ro method is predominantly used for loading vehicles onto ships. This process involves driving vehicles directly onto the ship, where they are securely fastened. Spanish ports are equipped with advanced systems to handle a high volume of vehicles efficiently [37].

- Regulatory Framework: Spain, being part of the European Union, adheres to EU regulations regarding maritime transport. This includes environmental regulations, safety standards, and customs procedures. Spanish ports are often audited for compliance with international shipping standards [38].

- Shipping Routes: Spain's geographical location offers strategic advantages for vehicle shipping. The ports serve

as gateways to Africa, the Middle East, and Latin America, in addition to connecting with other European ports. This makes Spain a critical node in the global automotive shipping network [39].

- Technological Advancements: Spanish ports utilize advanced technology for logistics management, including digital tracking systems, automated scheduling, and RFID tagging for real-time tracking of vehicles [40].

- Environmental Considerations: Spanish ports and shipping companies are increasingly adopting eco-friendly practices, such as using ships with lower sulfur emissions and exploring alternative fuels like LNG (Liquefied Natural Gas) [41].

- Challenges and Opportunities: The Spanish vehicle shipping sector faces challenges like fluctuating global trade patterns and economic fluctuations. However, there are opportunities in expanding capacity and enhancing technological integration [42].

3.3. The transport of electric and hybrid vehicles on board ships.

3.3.1. On-board fires caused by electric and hybrid vehicles.

Fires on board ships caused by electric vehicles (EVs) and hybrids are an area of growing concern in the maritime industry [43]. Although fires in EVs are no more common or intense than fires in internal combustion engine vehicles (ICEVs), lithium-ion batteries in EVs present unique challenges, especially in the context of a maritime environment [44].

First, we will discuss here the accident of the Felicity Ace (IMO 9293911) a representative case that highlights the risks associated with the maritime transport of EVs. On 16 February 2022, the Felicity Ace, a vehicle cargo ship built in 2005, suffered a fire while transiting the Atlantic [45]. On board were approximately 4,000 vehicles, including models from luxury brands such as Porsche, Audi, Bentley and Lamborghini, along with lithium-ion batteries.

Figure 6: Felicity Ace on fire.

Source: Marinha PT.

The ship's crew was safely evacuated, and no injuries were reported among the 22 crew members. However, the fire persisted for two weeks, making extinguishing operations difficult due to the nature and location of the fire on the vessel. Efforts to tow the vessel began on 24 February, but on 1 March 2022, during the towing process, the Felicity Ace lost stability and eventually sank some 25 nautical miles outside Portugal's exclusive economic zone, at a depth of approximately 3000 metres [46].

The estimated value of the vehicles on board was estimated at around $401 million [47]. Although the lithium batteries in the electric vehicles on board were identified as a factor that could have contributed to the intensity of the fire, the exact cause of the fire has not been definitively determined, but it is believed that the lithium batteries in some of the electric vehicles being transported made it very difficult to control and extinguish the fire, which ultimately led to the abandonment of the vessel and its subsequent sinking. The ship was carrying more than 100 purely electric vehicles, of the Audi E-Tron model [48]. In fact, some media reported that a few years earlier in 2019, owners of this vehicle model were invited by the brand to attend the dealership to check the wiring as the brand had reported that its batteries were at risk of catching fire due to a design error [49]. Anecdotally, there was a collision between an Audi E-Tron in Canada and another vehicle at a traffic light, where the Audi's battery became detached from the vehicle due to the collision and subsequently caught fire [50]. The industry of vehicles with lithium-ion batteries is growing rapidly due to high demand, so it is not uncommon that, as with almost any product that is put on the market, manufacturing errors are detected afterwards which, although they are rectified over time, cause major problems for users, for example in the automotive sector there are currently many users who report problems due to failures in the MCI 1. 2 l three-cylinder Puretech 110 or 130 hp engines from the defunct PSA group manufactured between 2013 and 2017, with more than 200,000 vehicles affected [50]. As we can see, these are not isolated to EVs, but they are issues that need to be considered because of the risks involved.

Figure 7: Battery pack of an Audi e-tron is seen being ejected from the EV and onfire.

Source: electrck.co.

The sinking of the Felicity Ace highlighted the unique challenges presented by electric vehicle shipping, including the management of fire risks associated with lithium-ion batteries [52].

Research by EU Project LASHFIRE, with IUMI participation, indicates that neither the rate of fire growth nor the maximum heat release rate or total energy released during a fire is higher in an EV fire than in an ICEV fire [53]. However, it is

highlighted that exposure of lithium-ion batteries to fire can result in thermal runaway, which requires a different approach to fire detection and response.

In addition, the challenge of extinguishing battery fires on ships is complex due to limited space conditions, making it difficult for firefighters to access and use traditional firefighting tactics. Shipping companies are implementing measures such as specifying a minimum and maximum state of charge for EV batteries and developing specialised methods for battery fire suppression [54] [55].

Just over a year later, another such incident occurred again on board a vessel carrying both conventional and electric vehicles. The fire on the Fremantle Highway was a significant incident that again raised concerns about the safety of electric vehicle (EV) shipping. The fire occurred on 25 July while the vessel was en route from Germany to Egypt, off the coast of the Netherlands. The Fremantle Highway was carrying nearly 4,000 cars, including approximately 500 EVs. One crew member lost his life and others were injured, some having to jump overboard to escape the flames [56].

Figure 8: Fremantle Highway on July 28th.

Source: Kustwacht Nederland.

Figure 9: Inside Fremantle Highway.

Source: RTL.

Initially, it was speculated that an EV might have been the cause of the fire. However, subsequent investigations suggested that the fire might not be related to the EVs and could have been caused by an internal combustion vehicle (ICE) or some other cause [57]. Reports indicate that the four lower decks of the vessel, where the EVs were located, were largely intact, while the four upper decks were severely damaged, with vehicles completely charred in place. Despite initial speculation, the cause of the fire has not yet been officially determined. The International Maritime Organisation (IMO) and the International Union of Marine Insurance (IUMI) are investigating the fire risks associated with EVs on ships [58].

The incident has highlighted the need for greater understanding and management of the risks associated with transporting electric vehicles on ships, including the possibility of fires and the difficulty of fighting them at sea.

3.3.2. Cause of this fires aboard.

The main causes of fires in electric and hybrid vehicles on passenger ships include lithium-ion battery problems, short circuits, overheating and damage to the battery management system. The transport of electric cars on ships has been linked to fires due to the possibility of lithium-ion batteries emitting smoke containing hydrogen fluoride, an extremely harmful substance.

Fires involving lithium-ion batteries have long been a challenge for both fire-fighting services and preventive measures, for several reasons, but mainly because they are not very predictable: while some batteries may burn during charging, others, for example, may burn due to contact with salt water, and others simply due to design flaws [59]. On the other hand, ship garages tend to organise vehicles in such a way as to make the best use of space, so that sometimes it is very difficult even for people to pass between two parked vehicles and in the event of an emergency, extinguishing can be delayed due to difficulties in accessing the vehicle and, on the other hand, the spread of the fire is very rapid because it quickly affects the other vehicles around it, just a few tens of centimetres away. And finally, the very chemical nature of the battery itself, with multiple specific chemical components, also makes it very difficult to extinguish.

Figure 10: Electric car on fire on a ferry from Oslo to Copenhagen in 2010, photo by MsCandy.

Source: International Fire Protection Magazine.

It has been demonstrated with real evidence that fires from electric vehicles can pose a risk in maritime transport, leading to the adoption of specific safety measures on some ships. These

causes have raised concerns in the maritime industry and have prompted the implementation of safety protocols to mitigate the risk of fires on ships carrying electric and hybrid vehicles [60].

3.3.3. Safety measures to prevent fires on electric and hybrid vehicles on passenger ships.

In many different countries, a number of safety measures are being implemented to prevent fires from electric and hybrid vehicles on passenger ships. Some of these measures include [61]:

- Strict safety protocols: Some shipping lines have implemented stringent safety protocols for the boarding and transport of electric vehicles, including taking the temperature of vehicles on board with a heat gun and placing fire blankets in case of fire.
- Training of personnel in electric vehicle firefighting: Some shipping lines are training their personnel in electric vehicle firefighting, and have incorporated fire detection and extinguishing equipment on their vessels specifically for electric vehicles.
- Development of monitoring tools and technologies: Tools are being developed to monitor the temperature of vehicles, such as ground-based drones and sensor arcs to detect hot spots in vehicles, in order to prevent fires.

These measures seek to mitigate the risk of fires on ships carrying electric and hybrid vehicles, and reflect the growing concern for safety in the maritime transport of this type of vehicle. At the European level, we can highlight the LASH FIRE initiative [62], a project promoted by the European Commission following several EMSA studies on maritime fires on Ro-Ro and Ro-Pax vessels, where thirty serious fires on this type of vessel have been reported in barely a decade. Despite this, the fear of these fires in electric and hybrid vehicles is still very topical, to the point where some shipping companies have refused to embark electric vehicles despite having the required ticket and arguing the growing concern in the sector about the risk of fire in these vehicles [63].

Conclusions

Fires in electric and hybrid cars on ships are a topic of growing interest and concern in the maritime industry. Several important conclusions can be drawn from reported incidents and research:

- Increased Potential Risk: Electric and hybrid vehicles, due to their lithium-ion batteries, present a potentially increased risk of fire compared to internal combustion vehicles. This is due to the possibility of batteries undergoing what is known as ”thermal runaway”, a process where excessive heat can cause a fire.
- Fire Fighting Challenges: Fires involving lithium-ion batteries are particularly difficult to extinguish. They may require large amounts of water or special extinguishing agents, and there is a risk of rekindling the fire due to the nature of the batteries.
- Need for Specific Protocols: The safe management of electric and hybrid vehicles on board ships requires specific protocols, both in terms of storage and handling and emergency response. This includes proper segregation of these vehicles from other types of cargo and specialised training for ship's crew.
- Evolving Research and Regulations: Organisations such as the International Maritime Organisation (IMO) are actively investigating the risks associated with the carriage of electric and hybrid vehicles. This could lead to the implementation of new regulations and safety standards in the future.
- Importance of Manufacturer Cooperation: Manufacturers of electric and hybrid vehicles play a crucial role in this scenario, as their collaboration is essential to better understand the risks and develop effective prevention and response strategies.
- Environmental and Safety Impact: Although electric and hybrid vehicles are promoted for their lower environmental impact, safety risks, especially in maritime transport, must be carefully assessed and managed to ensure a balance between sustainability and safety.

In conclusion, the transport of electric and hybrid vehicles on ships represents an emerging safety challenge. A proactive approach is needed, including continuous research, development of specific safety protocols, collaboration between stakeholders and adaptation to new technologies and associated risks.

References.

[1] F. M. Moreno, «Vehículos Eléctricos. Historia, Estado Actual Y Retos Futuros,» European Scientific Journal, ESI, vol. May, pp. 118-131, 2016.

[2] M. M. d. Miguel, «Análisis sobre las plataformas de coches eléctricos.,» Universidad Politécnica de Valencia, Valencia, 2021.

[3] Ihobe S.A., «Comparativa ambiental entre diferentes alternativas de vehículos: Eléctrico, híbrido y combustión,» Ihobe Sociedad Pública de Gestión Ambiental. Departamento de Medio Ambiente, Planificación Territorial y Vivienda. Gobierno Vasco., Bilbao, 2020.

[4] I. Husain, Electric and Hybrid Vehicles: Design Fundamentals, Boca Raton: CRC Press, 2021.

[5] C. C. M. e. al., «Comparative Study of a Regenerative Braking System and Regeneration with Constant Kinetic Energy in Battery-based Electric Vehicles,» Ingeniería, vol. 25, nº 3, pp. 305-322, 2020.

[6] J. M. H. y. N. I. González, «Las infraestructuras de recarga y el despegue del vehículo eléctrico,» Observatorio Medioambiental , vol. 18, pp. 54-85, 2015.

[7] DAFO BRAND AKTIEBOLAG, «An Automated HEV and EV Vehicle Fire Early Warning and Suppression System. Li-IonFire.,» H2020-SMEInst-2014-2015, Sweden, 2015.

[8] VVAA, «La Movilidad Sostenible del futuro y el impacto sobre los ODS,» III Observatorio de la Movilidad Sostenible. Mobility City, F. Ibercaja & Grant Thornton. , Zaragoza, 2022.

[9] Ernst & Young Global Limited (EYG), «El mercado del vehículo eléctrico aumenta un 55% a nivel mundial,» Ernst & Young Global Limited (EYG), 18 mayo 2023. [En línea]. Available: https://www.ey.com/es_es/news/2023/05/el-mercado-vehiculo-electrico-aumenta-55-nivel-mundial#:~:text=La%20venta%20del%20veh%C3%ADculo%20de,despliegue%20definitivo%20del%20veh%C3%ADculo%20el%C3%A9ctrico. [Último acceso: 26 octubre 2023].

[10] Mordor Intelligence Private Limited, «Análisis del tamaño y la participación del mercado de automóviles híbridos tendencias de crecimiento y pronósticos (2023 - 2028),» Mordor Intelligence Industry Reports, Telangana - India, 2023.

[11] IEA, «Global electric car stock, 2010-2022,» International Agency Energy, 5 abril 2023. [En línea]. Available: https://www.iea.org/data-and-statistics/charts/global-electric-car-stock-2010-2022. [Último acceso: 12 octubre 2023].

[12] IEA, «Informe Global EV Outlook 2021 sobre movilidad eléctrica,» International Energy Agency, abril 2021. [En línea]. Available: https://esmovilidad.mitma.es/noticias/informe-global-ev-outlook-2021-sobre-movilidad-electrica. [Último acceso: 03 octubre 2023].

[13] IEA, «Informe Global EV Outlook 2022 sobre vehículo eléctrico,» Agencia Internacional de la Energía, Mayo 2022. [En línea]. Available: https://esmovilidad.mitma.es/noticias/informe-global-ev-outlook-2022-sobre-vehiculo-electrico. [Último acceso: 12 octubre 2023].

[14] S. S. D. K. N. e. a. Afandizadeh, «Using machine learning methods to predict electric vehicles penetration in the automotive market,» Scientific Reports, vol. 13, nº 8345, 2023.

[15] J. B. B. e. al., Energy prices and electric vehicle adoption, Cambridge: National Bureau of Economic Research, March, 2022.

[16] K. e. al., «Google Trends and vehicle sales: A correlation study.,» Scientific Reports, 2023. W567W8504[17] ITDP, «What Is A Low Emission Zone?,» Institute for Transportation & Development Policy, New York, 2023.

[18] MITECO, «Directrices para la creación de zonas de bajas emisiones (ZBE),» Ministerio para la Transición Ecológica y el Reto Demográfico, Madrid, 2021.

[19] J. M. V. M. e. al., Impacto en la aceptabilidad y reparto modal de las medidas para mejorar la calidad del aire en Madrid Central, Burgos.: Universidad de Burgos. Servicio de Publicaciones e Imagen Institucional, 2021.

[20] A. Otero, «Estas son las ZBE ya activas y así restringen a los coches con etiqueta B y C de la DGT,» Motor Pasión, 25 septiembre 2023. [En línea]. Available: https://www.motorpasion.com/futuro-movimiento/estas-zbe-activas-asi-restringen-a-coches-etiqueta-b-c-dgt. [Último acceso: 10 octubre 2023].

[21] BOE, «Real Decreto 1052/2022, de 27 de diciembre, por el que se regulan las zonas de bajas emisiones.,» Ministerio de la Presidencia, Relaciones con las Cortes y Memoria Democrática. Agencia Boletín Oficial del Estado, Madrid, 2022.

[22] IDAE, «Guía para la promoción del vehículo electrico en las ciudades,» Instituto para la Diversificación y Ahorro de Energía, Madrid, 2011.

[23] BOE, «Orden PCI/810/2018, de 27 de julio, por la que se modifican los anexos II, XI y XVIII del Reglamento General de Vehículos, aprobado por Real Decreto 2822/1998, de 23 de diciembre.,» Boletín Oficial del Estado. Ministerio de la Presidencia, Relaciones con las Cortes e Igualdad, Madrid, 2018.

[24] IDAE, «PLAN MOVES. INCENTIVOS A LA MOVILIDAD EFICIENTE Y SOSTENIBLE,» Instituto para la Diversificación y Ahorro de la Energía., 26 febrero 2019. [En línea]. Available: https://www.idae.es/ayudas-y-financiacion/para-movilidad-y-vehiculos/convocatorias-cerradas/plan-moves-incentivos-la. [Último acceso: 11 octubre 2023].

[25] G. Ficarazzi, «Recursos y retos de la extinción de incendios en coches eléctricos,» Cuadernos de Seguridad, 14 junio 2023. [En línea]. Available: https://cuadernosdeseguridad-.com/2023/06/incendios-en-coches-electricos/. [Último acceso: 09 octubre 2023].

[26] UNCTAD, «Review of Marítime Transport,» United Nations Publications , New York, 2022.

[27] BIMCO et al., «Global Counter Piracy Guidance for Companies, Masters and Seafarers,» Witherby Publishing Group Ltd , Scotland, UK, 2018.

[28] Cross Country Car Shipping, «How Are Cars Loaded Onto Ships? (Detailed guide),» 8 junio 2023. [En línea]. Available: https://vernonnector.medium.com/how-are-cars-loaded-onto-ships-detailed-guide-ea4b8d035867. [Último acceso: 8 octubre 2023].

[29] EMSA, «European Maritime Safety Report 2022,» European Maritime Safety Agency, Luxembourg, 2022.

[30] A. Fedorenkova, «EU's Role in International Environmental Politics, does it help?: Interplay between IMO and EU Oil Pollution Regimes,» Environmental Policy Group. Wageningen University , Paises Bajos, 2007.

[31] J. Tan, «What Is Marine Cargo Insurance, And Why Is It Important?,» MGS Offshore, 15 febrero 2023. [En línea]. Available: https://mgsicestorm.com/marine-cargo-insurance/. - [Último acceso: 06 octubre 2023].

[32] M. S. S. Weng Chun Tan, «Review of RFID and IoT integration in supply chain management,» Operations Research Perspectives, vol. 9, nº 100229, 2022.

[33] H. K. Z. H. M. Veronica Jaramillo Jimenez, «A review of ship energy efficiency research and directions towards emission reduction in the maritime industry,» Journal of Cleaner Production, vol. 366, nº 132888, 2022.

[34] O. A. L.-D. C. P. M. G. F. A. Ortega, «Maritime Transport as a Key Element in the Automotive,» - JMR - Journal of Maritime Research, vol. X, nº 3, pp. 79-82, 2013.

[35] A. M. e. al., «Seaport capacity manual: Application to container terminals,» Fundación VALENCIAPORT, Valencia, 2012.

[36] S. D. Judit Montoriol Garriga, «Spain's automotive industry: strategic and undergoing a transformation,» Caixabank Research, 14 julio 2021. [En línea]. Available: https://www.caixabankresearch.com/en/sector-analysis/industry/spains-automotive-industry-strategic-and-undergoing-transformation. [Último acceso: 03 octubre 2023].

[37] A. G. Camps, «Car carrier operational guide and proposal for an optimization system,» Universitat Politècnica de Catalunya , Barcelona, 2020.

[38] European Parliament, «Maritime transport: Traffic and safety rules,» European Parliament, abril 2023. [En línea]. Available: https://www.europarl.europa.eu/factsheets/en/sheet/125/-maritime-transport-traffic-and-safety-rules. [Último acceso: 03 octubre 2023].

[39] R. K. Arnaud Serry, «Spanish container ports integration in the maritime network,» JMR - Journal of Maritime Research, vol. 17, nº 3, pp. 10-17, 2020.

[40] G. &. B. B. &. B. E. Casella, «The evolution of RFID technology in the logistics field: a review.,» Procedia Computer Science., nº 200, pp. 1582-1592, 2022.

[41] G. F. Patrizia Serra, «Towards the IMO's GHG Goals: A Critical Overview of the Perspectives and Challenges of the Main Options for Decarbonizing International Shipping,» Sustainability , vol. 12, nº 8, p. 3220, 2020.

[42] F. Alanazi, «Electric Vehicles: Benefits, Challenges, and Potential Solutions for Widespread Adaptation,» Applied Sciences, vol. 13, nº 10, p. 6016, 2023.

[43] Todotransporte.com, «Las baterías de los vehículos eléctricos preocupan a los trasportistas marítimos,» Todotransporte-.com, 1 diciembre 2022. [En línea]. Available: https://www.todotransporte.com/texto-diario/mostrar/4094377/baterias-vehiculos-electricos-preocupan-trasportistas-maritimos. [Último acceso: 03 octubre 2023].

[44] C. M.-G. Mohd Zahirasri Mohd Tohir, «Electric vehicle fire risk assessment framework using Fault Tree Analysis,» Open Res Europe, nº 3, p. 178, 2023.

[45] S. Sharma, «Fire-wrecked cargo ship carrying thousands of luxury cars sinks after floating in Atlantic for weeks,» Independent.co.uk, 02 marzo 2022. [En línea]. Available: https://-www.independent.co.uk/news/world/americas/ship-fire-luxury-car-sink-atlantic-b2026499.html. [Último acceso: 04 octubre 2023].

[46] E. Haun, «Burnt Car Carrier Felicity Ace Sinks,» MarineLink, 1 marzo 2022. [En línea]. Available: https://www.marinelink.com/news/burnt-car-carrier-felicity-ace-sinks-494679. - [Último acceso: 02 octubre 2023].

[47] P. Holderith, «It's Been Exactly One Year Since the Felicity Ace Caught Fire With Nearly 4,000 Cars Onboard,» The Drive, 16 febrero 2023. [En línea]. Available: https://www.thedrive.com/news/its-been-exactly-one-year-since-the-felicity-ace-caught-fire-with-nearly-4000-cars-onboard. [Último acceso: 02 octubre 2023].

[48] M. Trueno, «Here's a list of cars that sank with the Felicity Ace car carrier,» CarExpert: Research, buy & sell with confidence, 03 abril 2022. [En línea]. Available: https://www.-carexpert.com.au/car-news/heres-a-list-of-cars-that-sank-with--the-felicity-ace-car-carrier. [Último acceso: 04 octubre 2023].

[49] D. Gutiérrez, «El Audi e-tron es llamado a revisión por un potencial riesgo de incendio,» LaSexta.com, 15 julio 2019. [En línea]. Available: https://www.lasexta.com/motor/noticias/-audi-etron-llamado-revision-potencial-riesgo-incendio_201906-115d0010f70cf21df7ccbe0e75.html. [Último acceso: 04 octubre 2023].

[50] F. Lambert, «Audi e-tron battery pack is seen ejecting during a crash,» Electrek, 02 febrero 2023. [En línea]. Available: https://electrek.co/2023/02/02/audi-e-tron-battery-pack--seen-ejecting-during-crash/. [Último acceso: 05 octubre 2023].

[51] Y. Lethuillier, «¿Hay problemas con el motor 1.2 PureTech del extinto Grupo PSA?,» Motor1.com, 20 abril 2023. [En línea]. Available: https://es.motor1.com/news/466419/motor-puretech-psa-llamada-revision/. [Último acceso: 01 octubre 2023].

[52] Rife Insights: Marine News. , «Everything about Felicity Ace Fire,» Rife Insights: Marine News. , 17 febrero 2022. [En línea]. Available: https://www.rifeconsultancy.com/news/-felicity-ace-fire/. [Último acceso: 06 octubre 2023].

[53] M. Schuler, «Burning Questions: Unraveling the Truth Behind Electric Vehicle Fires in Maritime Shipping,» gCaptain, 11 agosto 2023. [En línea]. Available: https://gcaptain.com/burning-questions-unraveling-the-truth-behind-electric-vehicle-fires-in-maritime-shipping/. [Último acceso: 02 octubre 2023].

[54] A. D. Lisa Baertlein, «Focus: Ocean shippers playing catch up to electric vehicle fire risk,» Reuters, 28 julio 2023. [En línea]. Available: https://www.reuters.com/business/autos-transportation/ocean-shippers-playing-catch-up-electric-vehicle-fire-risk-2023-07-27/. [Último acceso: 03 octubre 2023].

[55] E. Sutcliffe, «Electric vehicle fires on ships & ferries,» - EVFireSafe.com, 23 febrero 2022. [En línea]. Available: https:-//www.evfiresafe.com/post/electric-vehicle-fires-on-ships-ferries. [Último acceso: 04 octubre 2023].

[56] J. Gómez, «Las pérdidas por el incendio del buque Fremantle Highway superan los 274 millones de euros,» Diario de Transporte, 03 agosto 2023. [En línea]. Available: https://www.diariodetransporte.com/articulo/transporte-maritimo-y-puertos/perdidas-incendio-buque-fremantle-highway-superan-274-millones-euros/20230803145129085712.html. [Último acceso: 02 octubre 2023].

[57] J. Costas, «Continúa el misterio del incendio del Fremantle Highway,» Motor.es, 16 agosto 2023. [En línea]. Available: https://www.motor.es/noticias/kia-ev5-2024-fotos-espia--202396811.html. [Último acceso: 02 octubre 2023].

[58] J. M. R. Leal, «Las consecuencias del incendio del Fremantle Highway empiezan a salir a la luz,» Soymotor.com, 08 agosto 2023. [En línea]. Available: https://soymotor.com/coches-/noticias/las-consecuencias-del-incendio-del-fremantle-highway-empiezan-salir-la-luz. [Último acceso: 04 octubre 2023].

[59] L. Vicente, «¿Sueñan los cruceros con coches eléctricos?,»- Cottes Group, 02 febrero 2023. [En línea]. Available: https://www-.cottesgroup.com/blog/suenan-los-cruceros-con-coches-electricos. [Último acceso: 03 octubre 2023].

[60] J. J. C. Vega, «El riesgo latente: Incendios en transportes marítimos de vehículos eléctricos,» SigmaXpert Sure, 04 agosto 2023. [En línea]. Available: https://www.linkedin.com/-pulse/el-riesgo-latente-incendios-en-transportes-mar%C3%AD-

timos-de-c%C3%B3rdoba-vega/?originalSubdomain=es. [Último acceso: 03 octubre 2023].

[61] PiexNext, «Innovación en seguridad: el riesgo de incendios en los buques del futuro,» PiexNext - Innovation by Port de Barcelona., 28 octubre 2022. [En línea]. Available: https://piernext.portdebarcelona.cat/movilidad/innovacion-en-seguridad-el-riesgo-de-incendios-en-los-buques-del-futuro/. [Último acceso: 04 octubre 2023].

[62] Redacción Naucher, «Proyecto Lash Fire: la búsqueda de la seguridad para los buques Ro-Ro,» Naucher Global, 16 enero 2020. [En línea]. Available: https://www.naucher.com/proyecto-lash-fire-la-busqueda-de-la-seguridad-para-los-buques-ro-ro/. [Último acceso: 02 octubre 2023].

[63] CTIF, «Una naviera noruega prohíbe los coches eléctricos a bordo de un ferry clásico,» CTIF - International Association of Fire and Rescue Services, 07 febrero 2023. [En línea]. Available: https://www.ctif.org/es/news/una-naviera-noruega-prohibe-los-coches-electricos-bordo-de-un-ferry-clasico. [Último acceso: 01 octubre 2023].

JOURNAL OF MARITIME RESEARCH

Vol XX. No. III (2023) pp 251–258

ISSN: 1697-4840, www.jmr.unican.es

Measuring Efficiency of Mediterranean Ports Using Data Envelopment Analysis (DEA) Method

Abir Mhamdi[1], Rabeb Kammoun[2,*], Younès Boujelbene[3]

ARTICLE INFO

Article history:
Received 01 Aug 2023;
in revised from 20 Oct 2023;
accepted 27 Dec 2023.

Keywords:
efficiency, Mediterranean seaports, DEA-BCC, DEA-CCR.

ABSTRACT

The aim of this paper is to examine the efficiency of 37 Mediterranean seaports between 2005 and 2017 using the Data Envelopment Analysis (DEA) method. The results from two DEA models, DEA-BCC and DEA-CCR, indicate that ports like Genoa, Cagliari, Valencia, Tarragona, Port Said, Alexandria, and Tripoli demonstrate the highest efficiency scores. In contrast, Barcelona, Livorno, Arzew, Thessaloniki, and Latakia consistently exhibit inefficiency throughout the analysis period. The inefficiency in Mediterranean ports is attributed to overcapacity and trade fluctuations.

1. Introduction.

Maritime transport is a handling method that transports goods in large quantities over long distances, for small batches and short distances. A container terminal is divided into two main areas, each characterized by its own handling operations and equipment. Indeed, ships are loaded/unloaded by quay cranes. Meanwhile, the yard crane requires its own equipment, and another transport equipment ensures the connection between these two areas. To improve the efficiency of port operations, it is essential to identify and solve several optimization problems such as truck transport route planning, yard crane operations planning, quay crane operations planning, and container allocation in customs storage warehouses. In a container terminal, containers are stored in multiple levels called tiers. The position of a container in the yard is characterized by a specific address formed by block, bay, row, and tier. The maximum number of tiers depends on the handling equipment available in the terminal (Steenken et al., 2004). Moreover, according to the work of Chen and Langevin (2011), containers that are exported, loaded onto trucks, and structured on the quay are distributed and stored in a storage area. After a period, the containers are removed with yard cranes and transported by yard trucks to the retrieval quays using quay cranes and loaded onto ships.

Through the use of a container terminal system, several researchers have succeeded in improving the performance of ports and contributing to the reduction of congestion by planning, monitoring, and executing the movement of containers from one truck to another, from a truck to a boat, and from a boat to a truck (Hervás et al., 2019).

This work addresses a significant real-world problem related to the efficiency of major Mediterranean ports, based on the DEA method.

This work consists of 6 sections. In the second section, we provide a literature review on port performance. In the third section, we describe the DEA method. In the fourth section, we present the variables of efficiency for Mediterranean ports, then in the fifth section, we interpret the results obtained through the DEA method. Finally, in the sixth section, we provide a conclusion.

[1]Department of Research Laboratory in Economics and Management. Faculty of Management and Economics of Sfax, Tunisia. E-mail Address: abirmhamdikb@gmail.com.

[2]Department of Competitiveness, Business Decision and Internationalization, Faculty of Management and Economics of Sfax, Tunisia.

[3]Department of Research Laboratory in Economics and Management. Faculty of Management and Economics of Sfax, Tunisia.

[*]Corresponding author: Rabeb Kammoun. E-mail Address: rabebkammoun1989@gmail.com.

2. Literature Review: Port Performance.

The performance of ports is a crucial determinant for evaluating their competitiveness. Measuring port performance is a vital exercise in strengthening its competitiveness, providing a benchmark against which the port can be assessed in comparison to others.

Roll and Hayuth (1993) likely represented the first work to promote the application of the Data Envelopment Analysis (DEA) technique to the context of ports. However, their work remains purely theoretical, rather than a practical application. After this initial exploratory study, only six years later, another document was published. Martinez-Budria et al. (1999) classified 26 ports into three groups based on high, medium, and low complexity. Using the DEA-BCC model, the authors examined the efficiency of ports and concluded that high-complexity ports are associated with greater efficiency compared to medium and low efficiency in other port groups.

The DEA-CCR model, according to Valentine and Gray (2001), was applied to 31 container ports in 1998. They used two inputs: total length of quay berths and length of container berths, total freight volume, and the number of containers. They concluded that group analysis is a reliable tool for identifying organizational structures, and the port sector exhibits three structural forms that seem to be related to estimated levels of efficiency.

Barros (2003) applied the DEA approach to ten Portuguese seaports for the period 1999-2000. The versatile nature of national ports was represented by measuring the production of various types of cargoes (general cargo, bulk cargo, containerized cargo, solid bulk, and liquid bulk). The number of ships was also considered an output, while the number of employees and the book value of assets were adopted as inputs.

According to Nguyen et al. (2015), classical Data Envelopment Analysis (DEA) tends to be sensitive to the number of variables in a chosen sample and does not account for their random nature. Standard DEA may present statistical inconsistencies, biased results, and a debatable inference process. Therefore, this study uses a method of efficiency evaluation to overcome these limitations, especially as no study on port efficiency has addressed this issue. This study applies bootstrapped DEA to a sample of the 43 largest Vietnamese ports and compares the results with those of Stochastic Frontier Analysis (SFA) and standard DEA. The results show that efficiency scores obtained through these methods provide useful and consistent information about port efficiency. Furthermore, while efficiency scores are already introduced by bootstrapped DEA, the variables remain consistent and insensitive to sample size, making DEA and SFA yields much larger than DEA alone. Additionally, bootstrapped DEA provides efficiency scores and allows hypothesis testing of port performance.

The research presented in this article, according to Nikolina et al. (2020), focuses on small ports that have not received much attention until now. The strategic position of the ports in the northern Mediterranean has gained importance with Chinese investment. In the first half of 2019, Croatia and Italy agreed to participate in a project aiming to shorten the route between China and Central Europe by redirecting maritime routes to the ports of the Adriatic Sea. This article examines the technical and scale efficiency of 25 ports in Croatia, Italy, and Slovenia, as a possible precondition for investments. The research uses returns of variables from Data Envelopment Analysis (DEA) to scale a results-oriented model on a panel data sheet for 25 ports in the period 2009-2018. This research suggests that the number of efficient ports, in this case, is not directly related to the size of the port or the country in which it is located. However, larger ports are more often efficient. For all inefficient ports, DEA provides examples of best practices to which these ports should aspire, highlighting the practical implications of the work.

According to Ezebunwa et al. (2020), performance evaluation is a regular check that every organization adapts to regulate the performance of its establishment. It shows the relationships between outputs and input variables in organizations. The study aims to examine the performance of six Nigerian seaports between the periods 2012-2017 by applying Data Envelopment Analysis (DEA) models, general linear models, and multivariate analysis. The collected data cover the periods (2012-2017) for each port. The empirical result shows that the seaports operated efficiently. The results from the regression model and multivariate analysis reject the null hypothesis and accept that at a significance level of 5%, there is a significant relationship between input and output variables for each port.

Li et al. (2021) use a super-efficiency Data Envelopment Analysis (SE-DEA) approach. The SE-DEA model is superior to the basic DEA model as it allows for a more accurate and comprehensive categorization and ranking of container terminals' efficiency. In the basic model, if different Decision Making Units (DMUs) are efficient, their efficiency value is "1." However, in the SE-DEA model, the most efficient DMU is greater than "1." Based on the container throughput level in 2018, the top 20 Chinese container terminal companies were selected. Various production quotas were chosen as inputs, while container throughput was considered an output. The results show that the Shanghai terminal was ranked first. This study contributes to providing information on the Chinese container terminal industry to increase efficiency. It also provides practical and policy implications (e.g., improved terminal operations) for container terminals.

Wang et al. (2021) use the DEA-Malmquist model, selecting freight throughput, operating profit, and net profit as output indicators, and quay berth length, number of quay berths, assets, and operating expenses as input indicators. They calculate and study changes in the total factor productivity of ten ports from 2007 to 2018 and analyze the impact of efficiency changes and technological changes on total factor productivity. The results show that: (1) The total factor productivity of the ten ports as a whole has shown a downward trend over the past 11 years, mainly due to technological changes. (2) The financial crisis reduced the overall total factor productivity in a short time. (3) The adoption of active economic policies and the reform of the management system can significantly promote improvement in efficiency changes and technological changes. Finally, combined with the results of the empirical analysis, some sugges-

tions are put forward, such as increasing investments in scientific research, rational planning of scale, and deepening system reform, etc.

3. Methodology.

The DEA (Data Envelopment Analysis) technique, introduces concepts into a basic model. We find a CCR (1978) type model that evaluates overall efficiency and identifies sources of inefficiency, as well as the BCC (1984) model that distinguishes technical inefficiencies and scale inefficiencies to estimate technical efficiency at scale and identify variable or constant returns to scale. Finally, the model by Charnes, Cooper, Golany, Seiford, and Stutz (1985) attempted to connect DEA analysis to Charnes and Cooper's (1962) early analyses of inefficiency and, in this process, further link efficiency analyzed in Koopmans' (1951) research. The DEA method provides a comprehensive picture of an organization's performance and appears to be a particularly suitable tool for service organizations. Depending on the problem orientation (input orientation or output orientation), the DEA method has three extremely useful features (Charnes et al. (1995)):

- It is very useful in complex situations where there are multiple outputs and inputs asserted in different units of measurement.
- It characterizes each Decision Making Unit (DMU) by a single efficiency score.
- It indicates changes in inputs and outputs for the most efficient units.
- Charnes et al. (1995) provide an additional list of other advantages of the DEA method:
- By projecting inefficient units, it provides the improvement value for each DMU.
- It focuses on determining the frontier of the best unit. Each unit is compared to an efficient unit or a combination of efficient units.
- It does not require any restrictions on cost or production functions (inputs and outputs).

The advantages of the DEA method essentially rely on the fact that it is a non-parametric approach. In fact, these characteristics have made Data Envelopment Analysis a popular method in efficiency estimation.

In this study, we will adopt the input-oriented approach. Therefore, the dual mathematical formulation of the DEA-CCR model is as follows:

$$\text{DEA-CCR} \begin{cases} Min_{\theta,\lambda}\ \theta \\ Subject\ to \\ -Y_0 + \lambda Y \geq 0 \\ \theta X_0 - \lambda X \geq 0 \\ \lambda \geq 0 \end{cases}$$

Equation 1: Mathematical formulation of the DEA-CCR model

Where:

θ: is a sought scalar (it represents the efficiency score of DMU_I),

λ: vector of non-negative weights,

Y: is the m × n output matrix,

X: is the k × n input matrix.

Y_0 and X_0 are the observed output and input values, respectively, of DMU_0 and the DMU to be evaluated.

θ^* is the efficiency score of DMU_0 focused on inputs. If θ^* is equal to unity, current input levels cannot be reduced, indicating that DMU_0 is efficient. However, if $\theta^* < 1$, then DMU_0 is technically inefficient.

The DEA-CCR problem (1) incorporates an additional constraint, the convexity constraint $N1'\lambda = 1$, where N1 is the n × 1 vector of 1s.

$$\text{DEA-BCC} \begin{cases} Min_{\theta,\lambda}\ \theta \\ Subject\ to \\ -Y_0 + \lambda Y \geq 0 \\ \theta X_0 - \lambda X \geq 0 \\ N1'\lambda = 1 \\ \lambda \geq 0 \end{cases}$$

Equation 2: Mathematical formulation of the DEA-BCC model.

4. Data Description.

The ports studied in this chapter are located in the Mediterranean region and are represented by twelve countries: France, Spain, Italy, Algeria, Morocco, Greece, Turkey, Cyprus, Syria, Lebanon, Egypt, and Libya. The container ports used in this research, therefore, have diverse policies, management structures, and characteristics.

Figure 1: Location of Container Ports in the Mediterranean Area.

Source: www.aquarius.geomar.de.

Not only do port regulations differ, but the size of ports also varies significantly. From the port throughput, we can observe the different sizes of ports that can be classified as small ports, as their throughput is less than 500000 EVP, while other ports are relatively large, with a throughput exceeding 2000000 EVP. The analysis, therefore, encompasses a wide range of port sizes in the Mediterranean basin.

In this study, the data consists of 481 annual observations. We use data from 37 Mediterranean seaports between 2005 and

2017. We use the database to calculate inputs, outputs, and efficiency explanatory variables. The choice of inputs and outputs depends primarily on the actual goal of the port authority and the sample size (for the DEA method to yield reasonable results, the sum of inputs and outputs should not exceed half the sample size) and the availability of data.

The container port's container throughput crucially depends on the efficient use of labor, land, and equipment. Therefore, the total number of quay berths, terminal area, number of quay cranes, and the number of workers are highly appropriate elements to be incorporated into the models as input variables.
Inputs:

- X1: Number of containers
- X2 : Number of passengers
- X3 : Number of ships
- X4: Surface area
- X5 : Depth
- X6: Number of cranes
- X 7: Petroleum products
- X 8 :Chemical products
- X 9: Solid bulk
- X 10: Liquid bulk
- X 11 : Dry products.

Outputs:

- Y: EVP: a unit of container measurement that includes both 20-foot and 40-foot containers.

Table 1: Descriptive statistics.

Factors	Obs	Mean	Std. Dev.	Min	Max
Y	481	1113035	1156637	1000	4832000
X1	481	2488349	5032531	1000	41100000
X2	481	1512235	1779857	1000	9028000
X3	481	2836.867	4900.668	1	29752
X4	481	80.31081	74.10905	2.3	431
X5	481	12.80811	3.352337	6	21.5
X6	481	13.0894	9.082854	1	53
X7	481	4033624	9837637	34000	64200000
X8	481	2663084	4552992	11000	25900000
X9	481	3851965	6281234	1000	36100000
X10	481	5323426	7726367	6000	28800000
X11	481	1816881	1457878	18000	11900000

Source: Authors.

5. Empirical Analysis of Port Efficiency.

The following interpretations can be derived: The DEA score, calculated under constant returns to scale (DEA-CCR), provides general measures of the technical efficiency of ports. The results indicate that the ports of Genoa, Cagliari, Valencia, Tarragona, Port Said, Alexandria, and Tripoli represent the set of efficient samples. Throughout the period from 2005 to 2017, the analysis demonstrates that the efficiency scores obtained by these ports are the highest (==1).

In contrast, the ports of Barcelona, Livorno, Arzew, Thessaloniki, and Latakia are consistently inefficient throughout the analysis period. The results show that the port of Bejaia was efficient during the analysis period with efficiency ranging between 0.162 and 0.78. It is also noteworthy that the results for the port of Annaba vary, as it was efficient in the years 2013, 2015, and 2016. However, during the rest of the analysis period, it was efficient with an efficiency score ranging between 0.468 and 0.780.

In 2005, 2006, and 2007, the ports of Algiers, Valencia, Tarragona, Genoa, Gioia Tauro, Cagliari, Skikda, Piraeus, Port Said, and Alexandria were efficient with a score of 1, while other ports had efficiency scores ranging between 0.08 and 0.918. The port of Sete is relatively the most inefficient with a score of 0.008.

In 2008, it is found that the port of Civitavecchia is inefficient with a score between 0.025.

In 2009, on the other hand, the port of Algiers is efficient with a score of 0.821. The port of Sete is the most inefficient with a score of 0.024.

It is observed in 2010 and 2011 that the port of Sete is more inefficient (0.003) than the port of Piraeus, which achieved an efficiency score of 0.956.

We can derive the following interpretations: The DEA score, calculated under constant returns to scale (DEA-CCR), provides general measures of the technical efficiency of ports. The results indicate that the ports of Genoa, Cagliari, Valencia, Tarragona, Port Said, Alexandria, and Tripoli represent the set of efficient samples. Throughout the period from 2005 to 2017, the analysis demonstrates that the efficiency scores obtained by these ports are the highest (==1).

In contrast, the ports of Barcelona, Livorno, Arzew, Thessaloniki, and Latakia are consistently inefficient throughout the analysis period. The results show that the port of Bejaia was efficient during the analysis period with efficiency ranging between 0.162 and 0.78. It is also noteworthy that the results for the port of Annaba vary, as it was efficient in the years 2013, 2015, and 2016. However, during the rest of the analysis period, it was efficient with an efficiency score ranging between 0.468 and 0.780.

In 2005, 2006, and 2007, the ports of Algiers, Valencia, Tarragona, Genoa, Gioia Tauro, Cagliari, Skikda, Piraeus, Port Said, and Alexandria were efficient with a score of 1, while other ports had efficiency scores ranging between 0.08 and 0.918. The port of Sete is relatively the most inefficient with a score of 0.008 in 2005.

Table 2: The CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale) efficiency scores for the period 2005 to 2011.

Countries	PORT	2005			2006			2007			2008			2009			2010			2011		
		CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE
Spain	Algeciras	1	1	1	1	1	1	1	1	1	0.923	0.929	0.993	0.821	0.828	0.992	0.849	0.852	0.997	0.849	0.852	0.997
	Malaga	1	1	1	1	1	1	0.533	1	0.533	0.282	1	0.282	0.256	1	0.256	0.291	1	0.291	0.291	1	0.291
	Alicante	0.783	1	0.783	0.756	1	0.756	0.643	1	0.643	0.683	1	0.683	0.67	1	0.67	0.719	1	0.719	0.719	1	0.719
	Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Tarragona	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Barcelona	0.845	0.894	0.946	0.979	0.988	0.99	0.88	0.912	0.965	0.724	0.825	0.878	0.594	0.758	0.784	0.577	0.742	0.777	0.577	0.742	0.777
France	Sete	0.008	1	0.008	0.028	1	0.028	0.11	1	0.11	0.432	1	0.432	0.024	1	0.024	0.003	1	0.003	0.003	1	0.003
	Marseille	0.895	1	0.895	0.975	1	0.975	0.089	1	0.089	0.633	1	0.633	0.688	1	0.688	0.654	1	0.654	0.654	1	0.654
	Fos-sur-Mer	0.799	1	0.799	1	1	1	1	1	1	0.636	1	0.636	0.605	1	0.605	0.672	1	0.672	0.672	1	0.672
Italia	Genoa	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	La Spezia	1	1	1	0.77	1	0.77	0.798	1	0.798	0.766	1	0.766	1	1	1	1	1	1	1	1	1
	Livorno	0.397	0.881	0.451	0.387	0.717	0.539	0.519	0.935	0.555	0.3	0.654	0.459	0.511	1	0.511	0.396	0.911	0.435	0.396	0.911	0.435
	Civitavecchia	0.038	1	0.038	0.044	1	0.044	0.033	1	0.033	0.025	1	0.025	0.028	1	0.028	0.036	1	0.036	0.036	1	0.036
	Naples	0.465	1	0.465	0.478	1	0.478	0.496	1	0.496	0.274	0.995	0.275	1	1	1	0.308	0.888	0.347	0.308	0.888	0.347
	Gioia Tauro	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Salerno	0.456	1	0.456	0.419	1	0.419	0.384	1	0.384	0.777	1	0.777	0.516	1	0.516	0.348	1	0.348	0.348	1	0.348
	Cagliari	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Palermo	0.17	1	0.17	0.066	1	0.066	0.194	1	0.194	0.226	1	0.226	0.162	1	0.162	0.03	1	0.03	0.03	1	0.03
	Augusta	0.221	1	0.221	0.242	1	0.242	0.243	1	0.243	0.174	0.95	0.183	0.167	1	0.167	0.138	0.923	0.15	0.138	0.923	0.15
	Catania	0.028	1	0.028	0.054	1	0.054	0.045	1	0.045	0.704	1	0.704	0.117	1	0.117	0.135	1	0.135	0.135	1	0.135
Algeria	Algiers	0.918	1	0.918	1	1	1	0.542	1	0.542	0.593	1	0.593	1	1	1	1	1	1	1	1	1
	Annaba	0.603	1	0.603	0.608	0.997	0.609	0.534	0.991	0.54	0.468	0.902	0.519	0.508	0.956	0.531	0.744	0.983	0.757	0.744	0.983	0.757
	Arzew	0.112	0.714	0.157	0.126	0.714	0.176	0.105	0.714	0.147	0.112	0.714	0.157	0.106	0.714	0.149	0.089	0.73	0.122	0.089	0.73	0.122
	Bejaia	0.162	1	0.162	0.237	1	0.237	0.253	1	0.253	0.218	1	0.218	0.283	1	0.283	0.386	1	0.386	0.386	1	0.386
	Oran	0.684	1	0.684	0.497	0.874	0.569	0.41	0.976	0.42	0.523	0.963	0.543	0.259	0.803	0.323	0.811	1	0.811	0.811	1	0.811

Countries	PORT	2005			2006			2007			2008			2009			2010			2011		
		CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE
Algeria	Skikda	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Marocco	Tangier	1	1	1	0.761	0.886	0.86	0.606	0.759	0.799	0.812	0.917	0.886	1	1	1	0.565	0.823	0.687	0.565	0.823	0.687
Greece	Piraeus	1	1	1	1	1	1	1	1	1	0.679	1	0.679	0.8	1	0.8	0.956	1	0.956	0.956	1	0.956
	Thessaloniki	0.383	0.789	0.485	0.194	0.77	0.251	0.188	0.763	0.247	0.093	0.758	0.123	0.145	0.757	0.191	0.136	0.752	0.18	0.136	0.752	0.18
Turkey	Izmir	0.859	1	0.859	0.865	1	0.865	0.766	1	0.766	0.761	1	0.761	0.647	1	0.647	0.558	1	0.558	0.558	1	0.558
	Antalya	0.08	1	0.08	0.275	1	0.275	0.318	1	0.318	0.316	1	0.316	0.379	1	0.379	0.177	1	0.177	0.177	1	0.177
Cyprus	Limassol	0.6	1	0.6	0.501	1	0.501	0.575	1	0.575	0.234	1	0.234	0.307	1	0.307	0.404	1	0.404	0.404	1	0.404
Syria	Latakia	0.248	0.798	0.31	0.37	0.778	0.476	0.32	0.764	0.418	0.195	0.641	0.304	0.293	0.688	0.425	0.203	0.58	0.351	0.203	0.58	0.351
Libanon	Beirut	0.814	1	0.814	0.716	1	0.716	1	1	1	0.411	0.776	0.529	0.466	0.779	0.598	0.549	0.932	0.589	0.549	0.932	0.589
Egypt	Port-Saïd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Alexandria	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lybia	Tripoli	1	1	1	1	1	1	0.978	1	0.978	1	1	1	1	1	1	1	1	1	1	1	1

Source: Authors.

Table 3: The CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale) efficiency scores for the period 2012 to 2017.

Countries	PORT	2012			2013			2014			2015			2016			2017		
		CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE
Spain	Algeciras	0.939	1	0.939	1	1	1	0.949	1	0.949	0.937	1	0.937	0.943	1	0.943	0.781	0.89	0.877
	Malaga	0.143	1	0.143	1	1	1	0.227	1	0.227	1	1	1	0.257	1	0.257	1	1	1
	Alicante	0.681	1	0.681	0.855	1	0.855	0.771	1	0.771	0.655	1	0.655	0.609	1	0.609	0.609	1	0.609
	Valencia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Tarragona	1	1	1	1	1	1	1	1	1	0.704	1	0.704	0.568	1	0.568	0.283	1	0.283
	Barcelona	0.463	0.689	0.672	0.427	0.667	0.639	0.455	0.655	0.694	0.456	0.656	0.696	0.506	0.659	0.769	0.647	0.732	0.884
France	Sète	0.03	1	0.03	0.037	1	0.037	0.005	0.944	0.005	0.006	1	0.006	0.008	1	0.008	0.39	1	0.39
	Marseille	0.712	1	0.712	0.989	1	0.989	0.943	1	0.943	0.911	1	0.911	0.803	1	0.803	0.816	1	0.816
	Fos-sur-Mer	1	1	1	1	1	1	0.741	1	0.741	0.7	1	0.7	0.731	1	0.731	0.643	1	0.643
Italia	Genoa	1	1	1	1	1	1	1	1	1	1	1	1	0.83	1	0.83	0.87	1	0.87
	La Spezia	1	1	1	1	1	1	0.716	1	0.716	1	1	1	0.655	1	0.655	0.895	1	0.895
	Livorno	0.266	0.841	0.316	0.276	0.801	0.345	0.245	0.813	0.302	0.312	0.958	0.326	0.278	1	0.278	0.146	0.954	0.153
	Civitavecchia	0.032	1	0.032	0.037	1	0.037	0.035	1	0.035	0.036	1	0.036	0.035	1	0.035	0.034	1	0.034
	Naples	0.439	1	0.439	0.457	0.921	0.496	0.245	1	0.245	0.253	1	0.253	0.206	0.929	0.222	0.379	1	0.379
	Gioia Tauro	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Salerno	0.266	1	0.266	0.419	1	0.419	0.522	1	0.522	0.735	1	0.735	0.649	1	0.649	0.821	1	0.821
	Cagliari	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Palermo	0.042	1	0.042	0.049	1	0.049	0.04	1	0.04	0.052	1	0.052	0.094	1	0.094	0.024	1	0.024
	Augusta	0.19	0.916	0.207	0.152	0.788	0.193	0.201	1	0.201	0.245	0.958	0.256	0.493	1	0.493	1	1	1
	Catania	0.656	1	0.656	0.283	1	0.283	1	1	1	0.737	1	0.737	0.755	1	0.755	0.588	1	0.588
Algeria	Algiers	0.742	1	0.742	1	1	1	0.975	1	0.975	1	1	1	1	1	1	1	1	1
	Annaba	0.794	1	0.794	1	1	1	0.78	0.997	0.782	1	1	1	1	1	1	0.798	1	0.798
	Arzew	0.068	0.714	0.095	0.057	0.714	0.08	0.037	0.714	0.052	0.071	0.714	0.099	0.058	0.714	0.081	0.077	0.714	0.108
	Bejaia	0.544	1	0.544	0.243	1	0.243	0.362	1	0.362	0.78	1	0.78	0.56	1	0.56	0.501	1	0.501

Countries	PORT	2012			2013			2014			2015			2016			2017		
		CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE
Algeria	Oran	0.84	1	0.84	0.76	0.877	0.866	1	1	1	1	1	1	1	1	1	0.996	1	0.996
	Skikda	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Marocco	Tangier	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Greece	Piraeus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Thessaloniki	0.294	0.773	0.381	0.177	0.756	0.234	0.126	0.756	0.166	0.114	0.769	0.149	0.109	0.745	0.146	0.119	0.752	0.158
Turkey	Izmir	0.56	1	0.56	0.489	1	0.489	0.356	1	0.356	0.46	1	0.46	0.621	1	0.621	0.742	1	0.742
	Antalya	0.239	1	0.239	0.25	1	0.25	0.21	1	0.21	0.255	1	0.255	0.252	1	0.252	0.237	1	0.237
Cyprus	Limassol	0.305	1	0.305	0.249	1	0.249	0.474	1	0.474	0.14	1	0.14	0.246	1	0.246	0.266	1	0.266
Syria	Latakia	0.076	0.548	0.139	0.24	0.521	0.46	0.097	0.813	0.119	0.382	0.777	0.491	0.228	0.679	0.335	0.216	0.632	0.341
Libanon	Beirut	0.69	0.899	0.767	0.859	1	0.859	0.548	0.795	0.69	0.514	0.839	0.612	0.32	0.818	0.391	0.44	0.936	0.471
Egypt	Port-Saïd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Alexandria	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lybia	Tripoli	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Source: Authors.

In 2008, it is found that the port of Civitavecchia is inefficient with a score between 0.025.

In 2009, on the other hand, the port of Algiers is efficient with a score of 0.821. The port of Sete is the most inefficient with a score of 0.024.

It is observed in 2010 and 2011 that the port of Sete is more inefficient (0.003) than the port of Piraeus, which achieved an efficiency score of 0.956.

Referring to the efficiency scores with the DEA-BCC model, we observe that the ports (Valencia, Gioia Tauro, Cagliari, Skikda, Tangier, Piraeus, Port Said, Alexandria, and Tripoli) are efficient throughout the analysis period [2012-2017]. It is also noted that the results for the port of Annaba vary as it was efficient during the period [2012-2017]. However, during the rest of the analysis period, it was efficient with an efficiency of 0.780.

We notice that among the 37 analyzed ports, only the following ports have an efficiency score equal to 1 over the entire period: Algiers in 2005-2007, Malaga in 2005-2006, Valencia in 2005-2017, Tarragona in 2005-2014, Fos-sur-mer in 2006-2007-2012-2013, Genoa in 2005-2015, La Spezia in 2005-2009-2010-2011-2012-2013-2015, Gioia Tauro in 2005-2017, Cagliari in 2005-2017, Oran in 2014-2016, Skikda in 2005-2017, Tangier in 2005 and 2009, 2012-2017, Piraeus in 2005-2007 and 2012-2017, Port Said in 2005-2017, Alexandria in 2005-2017, and Tripoli in 2005-2017.

We observe that seven ports are inefficient throughout all years of the study (Barcelona, Livorno, Augusta, Arzew, Thessaloniki, Latakia, and Beirut), while the other ports are efficient, having obtained efficiency scores equal to 1. The results provided by the DEAP program give us an idea of the efficiency scores in a general sense, and then the scores for each firm. This program suggests projected values for the inputs or outputs used. By using these values in new iterations, the scores of inefficient firms improve each time until reaching the value of 1 for both BCC and CCR models. Similarly, when using TEU as an output, the scores, as projected by the DEAP program, are equal to 1 for both inefficient and efficient ports.

The DEAP program offers a projection for inefficient units by reducing the values of inputs and increasing the value of the output. Thus, the projection of variables maintains the constancy of inputs by increasing the output. The value given by the program corrects only the score of the BCC model, which becomes 1 after the first iteration. To correct the score of the CCR model, we attempted several iterations to achieve the necessary output value to obtain a score equal to 1.

To assist the port administration in handling the new output variables to achieve efficient scores while using the same quantities of inputs, the port administration must seek solutions to accommodate more ships and cargo to increase the scores of inefficient ports.

The results of our study identify several variables to improve port efficiency. The significance attributed to the availability of loading and unloading equipment and the competence of operating personnel is explained by the fact that dysfunction at this level leads to increased waiting times for ships, raising port costs on one hand and penalizing the carrier on the other, increasing the overall cost of import or export. Therefore, the concerned goods become non-competitive in a competitive environment.

Conclusions

Our empirical results confirm that the models adopted in maritime transport ports depend primarily on the characteristics of loading or unloading systems that differ from others across ships. This work also studied the foundations of DEA and demonstrated how DEA can be applied to measure the efficiency of Tunisian ports. The most frequently used models are DEA-CCR and DEA-BCC, corresponding respectively to constant returns to scale and variable returns to scale assumptions.

However, empirical results show that the majority of Mediterranean ports are efficient. This information is particularly useful for port managers or policymakers to decide on the scale of production. In contrast to other studies on port efficiency, this study attempts to explain inefficiency through variables under the control of operators.

Empirically, in our research, the results show that port improvement and efficiency depend on the characteristics of port structures. Maritime transport, in service of international trade, only reflects the trade imbalance that crosses the Mediterranean. The traffic of Mediterranean ports is shared among a significant number of ports, which exhibit considerable dispersion. Additionally, interport competition involves variability between ports. Similarly, trade in the Mediterranean maritime basin aims to improve trade relations between public and private operators in the maritime transport and logistics sector, as well as to improve maritime freight delivery times while contributing to the competitiveness of the transport and logistics sector.

The competence of operating personnel manifests itself in its influence on the quality of handling service and service speed. This situation is generally due to an overlap in the tasks and responsibilities of different operators. The quality of the handling service is a determining factor in customer loyalty and is often linked to the level of competition. A lack of competition does not promote the development of services or the improvement of the quality of services offered.

The interviewed shipowners at the port emphasize the importance of the following determinants: the availability of qualified workforce; the availability of loading and unloading equipment and sufficient infrastructure; the use of new communication technologies; and the simplicity of procedures and documentation. According to them, if these factors are confirmed in a port location, others will automatically assert themselves.

Going further in our analysis, we can say that the central determinants of the performance of the Mediterranean port are closely related to productivity and, consequently, profitability.

References.

Books.

Barros, C. P. (2003). The Measurement of Efficiency Of Portuguese Sea Port Authorities With DEA. International Jour-

nal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti, 30(3), 335–354.

Charnes, A. Cooper, W.W. Rhodes, E. (1978), Measuring the efficiency of decision-making units. Eur. J. Oper. Res. 2, 429–444.

Chen, L., Langevin, A. (2011). Multiple Yard Cranes Scheduling for Loading Operations in a Container Terminal, Engineering, 43, 1205-1221.

Ezebunwa, K. Chinyeaka, N., Nwoloziri, N., (2020). Recent Performance Appraisal of Six Nigerian Seaports Using Multivariate and Data Envelopment Analysis, World Journal of Advanced Engineering Technology and Sciences, 01(02), 001-020.

Hervás, P., Poveda, R., Molero, G., Santarremigia, F., Ferrando, J. (2019). Improving the Performance of Dry and Maritime Ports by Increasing Knowledge about the Most Relevant Functionalities of the Terminal Operating System (TOS), Sustainability, MDPI, vol. 11(6), pages 1-23,

Li, L. Seo, Y. Ha, M (2021), The Efficiency of Major Container Terminals in China: Super-Efficiency Data Envelopment Analysis Approach, Maritime Business Review, ISSN: 2397-3757.

Martinez, B., B.E., Diaz A.R., Navarro I.M., Ravelo M.T (1999). A Study of the Efficiency of Spanish Port Authorities Using Data Envelopment Analyses, International Journal of Transport Economics, Vol. XXVI, nº 2, pp. 237-253.

Nguyen, H., Nguyen, H., Chang, Y., Chin, T. H., Tongzon, J. (2015). Measuring Port Efficiency Using Bootstrapped DEA: The Case of Vietnamese Ports. Maritime Policy & Management, Taylor & Francis Journals, vol. 43(5), pages 644-659, July.

Nikolina, B.P.; Hua, Z.J. Technical and scale efficiency analysis of 25 nort Mediterranean ports: A data envelopment analysis approach. Int. J. Econ. Financ. 2020, 12, 55–63.

Roll, Y,. Hayuth, Y. (1993). Port Performance Comparison Applying Data Envelopment Analysis (DEA). Maritime Policy and Management, 20, 153-161.

Steenken, D., Voss, S., Stahlbok, R. (2004). Container Terminal Operation and Operations Research a Classification and Literature Review, OR Spectrum 26:3–49.

Valentine, V.F., Gray, R. (2001). The Measurement of Port Efficiency Using Data Envelopment Analysis. Proceedings of the 9th World Conference on Transport Research.

Wang, Y., Wang, Z., Yun, M., (2021). Research on Total Factor Productivity Mesaerement of Major Ports in China. Shandong Jiaotong University No.1508, Hexing Rd, Weihai City, Shandong Province, China, SSH, Vol. 12.