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Delphi-ISM analysis for Geotechnology-based Sustainability in Maritime Industry

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ABSTRACT

Geotechnology involves the strategic deployment and potential of technology, which can influence regional alliances and security. The exploration of maritime technology use offers a promising avenue for balancing sustainability, economy, and environmental concerns, requiring further investigation. This research analyzed the sustainability factors based on geotechnology in maritime industries, grounded in geotechnology and sustainability theories, using a qualitative descriptive statistical approach. The Delphi method and Interpretive Structural Modeling (ISM) were employed to analyze input from 12 experts. Delphi data analysis showed strong expert agreement on twelve out of sixteen proposed factors, including Infrastructure, Renewable Energy, Big Data Analytics, Resource Management, Pollution Control, Climate Change, Regulatory Compliance, Stakeholder Engagement, Innovation and Research, Waste Management, Safety Standards, and Data Transparency. In the ISM model, the driver hierarchy was structured across five levels: Level 1 contained a single driver, Innovation and Research (F9), while Level 5 included Infrastructure (F1), Pollution Control (F5), Regulatory Compliance (F7), Stakeholder Engagement (F8), and Waste Management (F10). No drivers were categorized as autonomous; instead, four factors were recognized as linkage, dependent, and driving variables, emphasizing the significance of all factors within the model.

1. Introduction.

The maritime industry is going through a big change in technology. New technologies like satellite navigation, electric propulsion, and smart sensors have made operations more efficient, safer, and more environmentally friendly (Kyaw, 2024). Emerging technologies, such as IoT, blockchain, AI, and neural networks, are are very important for solving environmental problems and making shipping by sea more efficient (Kaštelan et al., 2024). This shift is being driven by advancements in technology and collaboration among industry participants (Ichimura et al., 2022). This makes it possible to increase sustainability and production (Munim et al., 2020). Even still, issues persist, particularly with regard to supply chains, legal frameworks, and stakeholder perceptions (Okumus et al., 2023). Although there are still economic and technical issues to be resolved, research is still moving in the direction of increased sustainability and efficiency (Yusup, 2023). Technological advancements in maritime operations indicate a measured optimism, highlighting the importance of transparency and environmental stewardship (Lee et al., 2019). More research is needed on how slowly adopting maritime technologies can help meet economic, environmental, and sustainability goals (Barona et al., 2023).

Geotechnology, or the nexus of geopolitics and technology, is the focus of a parallel discourse that sheds light on how global power structures have changed during the Fourth Industrial Revolution (Nedelcu, 2024). Understanding how new technologies impact state power and global order is becoming increasingly crucial (Jaffrelot & Louédin, 2022). Geotechnology has strategic implications for maritime security and regional al-

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liances, particularly in the Indo-Pacific (Jaffrelot & Louédin, 2022). Kaštelan et al (2024) highlight the need for further studies to explore the balance between technological progress and sustainability and safety. The marine industry's comprehensive approach to sustainable development (Wang et al., 2020) and the contribution of innovation to long-term environmental goals (Pettit et al., 2018; Slack (2010) should be the subject of future research.

This research aims to analyze sustainability factors based on geotechnology within the maritime industries. In line with this objective, three research questions (RQs) have been identified for this research, which are formulated as follows:

RQ 1: What are the factors influencing geotechnology-based sustainability in the maritime industry?

RQ 2: What are the possible interrelationships among the influencing factors of geotechnology-based sustainability in the maritime industry?

RQ 3: How can the interactions among the influencing factors of geotechnology-based sustainability be analyzed and categorized?

There are many reasons why this research is important. First, it wants to know what the maritime industry's growth means for geotechnology as a whole and what kinds of conflicts could arise from technological tensions (Wong, 2020). Second, it talks about how important it is to get new technologies, methods, and tools for the maritime sector as geoeconomic and geotechnological changes happen. Third, it makes people worry that they will rely on technology more. Countries that use technologies from other countries may lose some control, especially when competition between technologies changes the way things work in a region and affects strategic decisions. Fourth, the study emphasizes the necessity of aligning geopolitical and geostrategic frameworks with the emerging geotechnological paradigm, considering the rapidly evolving power dynamics shaped by technological progress (Wrublack et al., 2015).

This study employs geotechnology and sustainability theories alongside a qualitative descriptive statistical methodology. It employs the Delphi method to identify the key factors influencing geotechnology-related sustainability in the maritime sector and utilizes Interpretive Structural Modeling (ISM) to examine the interrelationships among these factors. The MICMAC diagram is also used to sort the interactions in the ISM. The study investigates Indonesia, a maritime nation with prominent ports in Jakarta, Surabaya, Batam, and Makassar, drawing on insights from 12 experts as reported by Ben Ruben et al. (2023).

This research presents five novel contributions: (1) it identifies sustainability dimensions within geotechnological aspects of the maritime industry value chain; (2) it underscores the necessity for the integration of maritime technology to enhance operations; (3) it provides insights into how technology can effect change while prioritizing safety and sustainability; (4) it aids in the development of an integrated framework for assessing sustainability in the maritime sector; and (5) it offers stakeholders pragmatic guidance on leveraging technology to enhance operational efficiency and long-term sustainability.

2. Literature Review.

2.1. Geotechnology Theory.

As the Fourth Industrial Revolution advances, the strategic importance of technology continues to grow, positioning companies alongside nation-states and international organizations as key actors in global governance. From a geotechnological point of view, technology is making governance more democratic by giving new powerholders more power (Nedelcu, 2024). Geotechnology is a new field of study that looks at the relationship between geopolitics and technology. It looks at how new technologies, whether they are planned or not, change the power and influence of states (Wong, 2020) This encompasses the utilization of social media to galvanize liberal democratic initiatives and the implementation of sophisticated surveillance technologies by authoritarian governments (Yang, 2014).

Geotechnology not only promotes national interests but also mitigates hostile technological initiatives that jeopardize a nation's geopolitical objectives (Bhutani, 2019). It includes the rules that control its development and spread, as well as its effects on how states act and on global politics (Thiel, 2017). It emphasizes not only the technical progress of tools and infrastructure but also the influence of socio-economic systems, design principles, and cultural values on governance domestically and internationally. Technology is a strong force in modern geopolitics that shifts the balance of power around the world. It sets technical standards for telecommunications, militarizes cyberspace, and even changes the programming languages used to make apps (Wong, 2020).

2.2. Sustainability Theory.

Sustainability means being able to keep doing things, like processes, systems, or activities, for a long time without hurting the environment, the economy, or people's health and well-being (Vinila, 2024). It is a key source for making decisions about global policies on sustainable development. The idea is closely related to economic growth, fairness between generations, and ecological balance. It is often defined as ”development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Hajian & Kashani, 2021). Grober, (2014) goes on to say that sustainability is the ability to keep certain conditions stable over time, especially when it comes to caring for the environment and being responsible as an organization. This means doing everything possible to reduce negative effects and increase positive contributions to society and nature.

Sustainability theory is based on ideas that can change and adapt to things like changes in the economy and the weather. It encourages a comprehensive approach that combines environmental, social, and economic factors, with a focus on protecting biodiversity, cultural heritage, and social systems. The main idea behind this approach is that everyone who has a stake in the decision-making process should be involved in decisions that put protecting the environment first. Another important principle is accountability. This means that people and groups must be responsible for the effects of their actions on society, the economy, and the environment (Ruggerio, 2021).

3. Methodology.

The main goal of this study is to use an interpretive hierarchical modeling process to find out what factors affect geotechnology - based sustainability in the maritime industry. The study uses a two-phase sequential exploratory research design that combines the Delphi method with Interpretive Structural Modeling (ISM). The first step is to use the qualitative Delphi method to find the most important things that affect geotechnology - based sustainability. In the second phase, the ISM—a multi-criteria decision-making (MCDM) tool—is applied to establish interrelationships among these factors (see Figure 1).

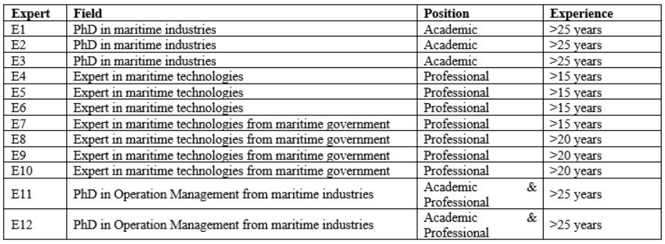
The research was conducted between 2024 and 2025 across four Indonesian cities with significant maritime industry activity: Jakarta, Surabaya, Batam, and Makassar. A panel of practitioners participated in identifying relevant factors and constructing the ISM model to reveal structural relationships among them. Subsequently, the model was expanded using MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) analysis to categorize the factors based on their driving and dependence power. The resulting geotechnology-based sustainability model provides a framework that is prioritized and can help decision-makers.

3.1. Selection criteria for the expert panel.

The Delphi method essentially emphasizes the careful selection of experts capable of providing informed insights into the research problem (Flanagan et al., 2016). In qualitative research, expert selection is critical, and providing demographic information about participants helps establish their credibility, experience, and relevance to the (Table 1). Experts should have both extensive practical experience and scientific knowledge, according to previous study (Moradi et al., 2023).

Experts were selected based on a number of factors, including years of professional experience, education level, and area of specialty, to ensure that the procedures were rigorous. According to Ali et al. (2023), there were two primary prerequisites: (1) being actively engaged in the marine industry and (2) have a solid grasp of the geotechnological underpinnings of the maritime environment and at least 15 years of experience. To ensure that the input was dependable and of the highest caliber, only those who fulfilled both criteria were allowed to participate. The legitimacy of the Delphi process is further strengthened by choosing experts who strike a balance between objectivity and domain involvement.

Table 1: Demographic information of the experts.



Expert	Field	Position	Experience
E1	PhD in maritime industries	Academic	>25 years
E2	PhD in maritime industries	Academic	>25 years
E3	PhD in maritime industries	Academic	>25 years
E4	Expert in maritime technologies	Professional	>15 years
E5	Expert in maritime technologies	Professional	>15 years
E6	Expert in maritime technologies	Professional	>15 years
E7	Expert in maritime technologies from maritime government	Professional	>15 years
E8	Expert in maritime technologies from maritime government	Professional	>20 years
E9	Expert in maritime technologies from maritime government	Professional	>20 years
E10	Expert in maritime technologies from maritime government	Professional	>20 years
E11	PhD in Operation Management from maritime industries	Academic & Professional	>25 years
E12	PhD in Operation Management from maritime industries	Academic & Professional	>25 years

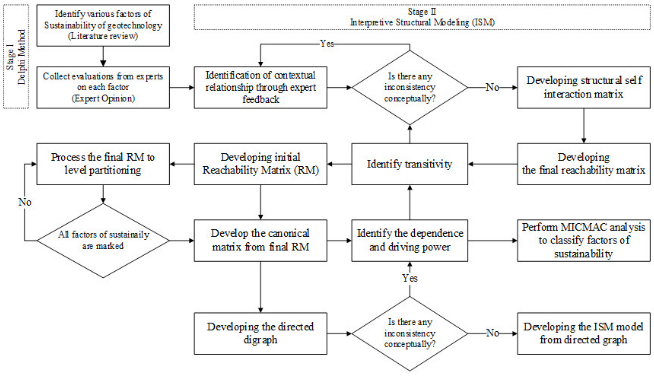
Source: Authors.

Google Forms was used to distribute questionnaires after experts were originally invited to participate via email in order to gather data. Experts were asked to evaluate the sustainability factors related to geotechnological elements during the pre-Delphi phase. According to Qureshi et al., (2022), the questionnaire used a 5-point Likert scale from 1 (Not Important) to 5 (Very Important).

The Content Validity Index (CVI) was computed by aggregating the relative frequencies of responses categorized as 4 (Agree) and 5 (Strongly Agree) as suggested by Mahran et al., (2021) to evaluate the degree of expert consensus on each item.

A CVI threshold of ≥ 0.75 was used to determine item adequacy (Coimbra et al., 2021). Items that arrived with expert recommendations or had a CVI below this threshold were modified and returned for evaluation. The CVI readings for each item were averaged to determine the instrument's total CVI. This ensured that in the subsequent Delphi rounds, only validated items were used.

Figure 1: Proposed research framework.



Source: Authors.

3.2. Delphi Technique.

Delphi methodology is an organized method for facilitating group discussions on complex issues so that everyone can reach a consensus and decide on the next course of action (Chand et al., 2020). From identifying the issue to selecting and sizing the expert panels to conducting the iterative Delphi rounds, the approach emphasizes meticulous planning at every point (Munasinghe et al., 2023). To ensure that the methods are consistent and the results are trustworthy, it is crucial to precisely identify the study problem, its objectives, and its scope (Jannat et al., 2020).

By incorporating experts and stakeholders through thorough inquiries in a practical context, the Delphi technique is particularly useful for identifying barriers and resolving ambiguity. According to Venkatesh et al., (2015), the approach typically consists of three basic steps: (1) assembling an expert panel; (2) identifying obstacles and devising a method of providing feedback; and (3) repeating the process numerous times. Obtaining panel members' consent to continue participating in each round is crucial because this approach relies on repeated processes (Rathore et al., 2022). To ensure that replies remain consistent and steady over time, it is crucial to maintain experts' motivation throughout the process (Ullah et al., 2021).

3.3. Interpretive Structural Modeling (ISM).

Interpretive Structural Modeling (ISM) is a method that relies on the agreement of experts and the judgment of a group. To systematically organize a set of interrelated components affecting a complex system into a coherent model, it employs a collaborative learning methodology (Wu et al., 2023). Originally introduced by Warfield (1974), its goal is to show the structural hierarchy of a system's determinants and to study how they interact with each other in an interactive way (He & Elhami Khorasani, 2022).

The phrase "interpretive" describes the method's reliance on professional judgment to ascertain the contextual relationships among variables. It is "structural" because it makes it possible to build a hierarchical model that explains the relationships between these variables. Furthermore, it is considered a modeling technique as it produces graphical representations of these relationships, offering clarity and a systematic understanding of the interdependencies within the system (Wu et al., 2023).

ISM is particularly useful in identifying and analyzing the structure of complex issues by breaking them down into manageable components. The method follows a step-by-step procedure that aids in constructing a directed graph or model The approach is a methodical process that helps create a directed graph or model that illustrates the direction and order of interactions between variables. The ISM methodology's main steps are listed below (Chand et al., 2020; Ullah et al., 2021):

- Factors influencing in the process are identified. This research outlines factors associated with sustainability from a geotechnology perspective.
- Contextual linkages among the examined factors are established.
- Pairwise relationships between factors are developed with the formulation of a Structural Self-Interaction Matrix (SSIM). These relationships are primarily represented using the VAXO method, with the notations V, A, X, and O.

Table 2: V, A, X and O by 1 and 0 in accordance with the VAXO rules.

Symbols	**V**	**A**	**X**	**O**
For (i, j)	1	0	1	0
For (j, i)	0	1	1	0

Source: Authors.

- A reachability matrix is constructed to examine transitivity. The transitivity rule assumes that if element A is related to B, and B is related to C, then A is indirectly related to C.
- The final reachability matrix is developed through the application of the transitivity rule and is divided into several levels.
- A directed graph (digraph) is drawn based on the relationships in the final reachability matrix, with transitive links being eliminated.
- The final digraph is then transformed into an Interpretive Structural Modeling (ISM) representation by replacing element nodes with corresponding statements.
- The theoretical interpretative structural model is reexamined for discrepancies and any necessary revisions are made to ensure the validity of the results.

3.4. MICMAC Analysis.

MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) analysis is a method for categorizing variables based on their direct and indirect correlations. It helps discover key factors affecting a system by assessing their driving power and dependability (Moradi et al., 2023). MICMAC analysis maps elements in a two-dimensional graph based on their interdependencies in geotechnology-based sustainability (Qureshi et al., 2022). Factors are then classified into four quadrants based on their driving power and dependency (Firmanto et al., 2024; Rathore et al., 2022).

- Autonomous (Quadrant I) - The factors in this quadrant show that they don't depend on each other much and don't have much driving power. They don't have much of an effect on the system because of this.
- Dependent (Quadrant II) - The factors in this quadrant depend on each other a lot, but they don't have a lot of driving strength. These factors are usually affected by other parts of the ISM model that are lower down.
- Linkage (Quadrant III) - The things in this quadrant are both very important and very powerful. These elements are considered unstable because any action involving them could have feedback effects that affect both themselves and other related factors.
- Independent or Driver (Quadrant IV) - Factors in this quadrant are regarded as the most critical, with strong driving power but weak dependence. This implies that they can significantly influence other factors. Therefore, these factors require immediate attention, as their impact can cascade through the system affecting several dependent variables.

4. Results.

4.1. Delphi method for geotechnology-based sustainability factors in the maritime industry.

Delphi method is an organized, iterative procedure that makes it easier for anonymous expert evaluations and logical improvement to lessen the impact of strong personalities and produce

Table 3: Results of the first, second and third rounds of expert judgment.

SN	Factors	Round 1		Round 2		Round 2		Code
		CVI	Result	CVI	Result	CVI	Result	
1	Infrastructure	1.00	Acceptable	1.00	Acceptable	1.00	Acceptable	F1
2	Renewable Energy	1.00	Acceptable	1.00	Acceptable	1.00	Acceptable	F2
3	Big Data Analytics	1.00	Acceptable	1.00	Acceptable	1.00	Acceptable	F3
4	Climate Resilience	0.67	Eliminate					
5	Resource Management	1.00	Acceptable	1.00	Acceptable	1.00	Acceptable	F4
6	Pollution Control	1.00	Acceptable	1.00	Acceptable	1.00	Acceptable	F5
7	Capacity Building	0.92	Acceptable	0.75	Eliminate			
8	Climate Change	0.83	Acceptable	0.83	Acceptable	0.92	Acceptable	F6
9	Regulatory Compliance	0.92	Acceptable	0.92	Acceptable	0.92	Acceptable	F7
10	Biodiversity Conservation	0.67	Eliminate					
11	Stakeholder Engagement	0.92	Acceptable	0.92	Acceptable	0.92	Acceptable	F8
12	Innovation and Research	0.83	Acceptable	0.83	Acceptable	0.92	Acceptable	F9
13	Economic Viability	0.75	Eliminate					
14	waste management	1.00	Acceptable	1.00	Acceptable	1.00	Acceptable	F10
15	safety standards	0.83	Acceptable	0.83	Acceptable	1.00	Acceptable	F11
16	Data Transparency	0.83	Acceptable	0.83	Acceptable	1.00	Acceptable	F12

Source: Authors.

more trustworthy results (Kumar et al., 2022). In this research, the method was used to identify resource-based sustainability factors in the maritime industry. A questionnaire based on interview sessions and a five-point Likert scale was administered in three rounds to twelve selected experts, including well-known, experienced executives. The Delphi method, along with other validated questionnaires, was used to compare geotechnology-based sustainability factors in the maritime industry, starting with an initial list of sixteen factors.

The Delphi results are summarized in Table 3. In the third round, feedback from the second round was presented and discussed. Experts expressed strong agreement on the importance of twelve model adjustment factors identified in the second round. Three rounds later, the Delphi process came to an end. After four criteria were eliminated, the study showed that experts strongly agreed with twelve of the sixteen suggested factors. Infrastructure, Renewable Energy, Big Data Analytics, Resource Management, Pollution Control, Climate Change, Regulatory Compliance, Innovation and Research, Waste Management, Safety Standards, and Data Transparency are the twelve factors that have been agreed upon. Climate resilience, biodiversity conservation, and economic viability were eliminated in the first round. Based on expert input, one more component (capacity building) was eliminated in the second round.

4.2. The reciprocal relationship between factors affecting geotechnological sustainability aspects in the maritime industry.

For analyzing the interrelationships of sustainability factors of geotechnology aspects, the ISM method was applied. The 12 experts who participated in the Delphi process were approached with the final list of sustainability factors derived after the third round. The contextual relationships between these 12 factors were assessed by determining how each pair of factors relates to one another.

Step 1: Data Gathering and Structural Self-Interaction Matrix (SSIM) Creation: The SSIM was created using the final model, which included the 12 elements found using the Delphi technique (Table 4). The contextual linkages between the parameters, as revealed by the experts' feedback, served as the basis for the development of this matrix. Table 5 presents the final relationships.

Step 2: Reachability matrix.

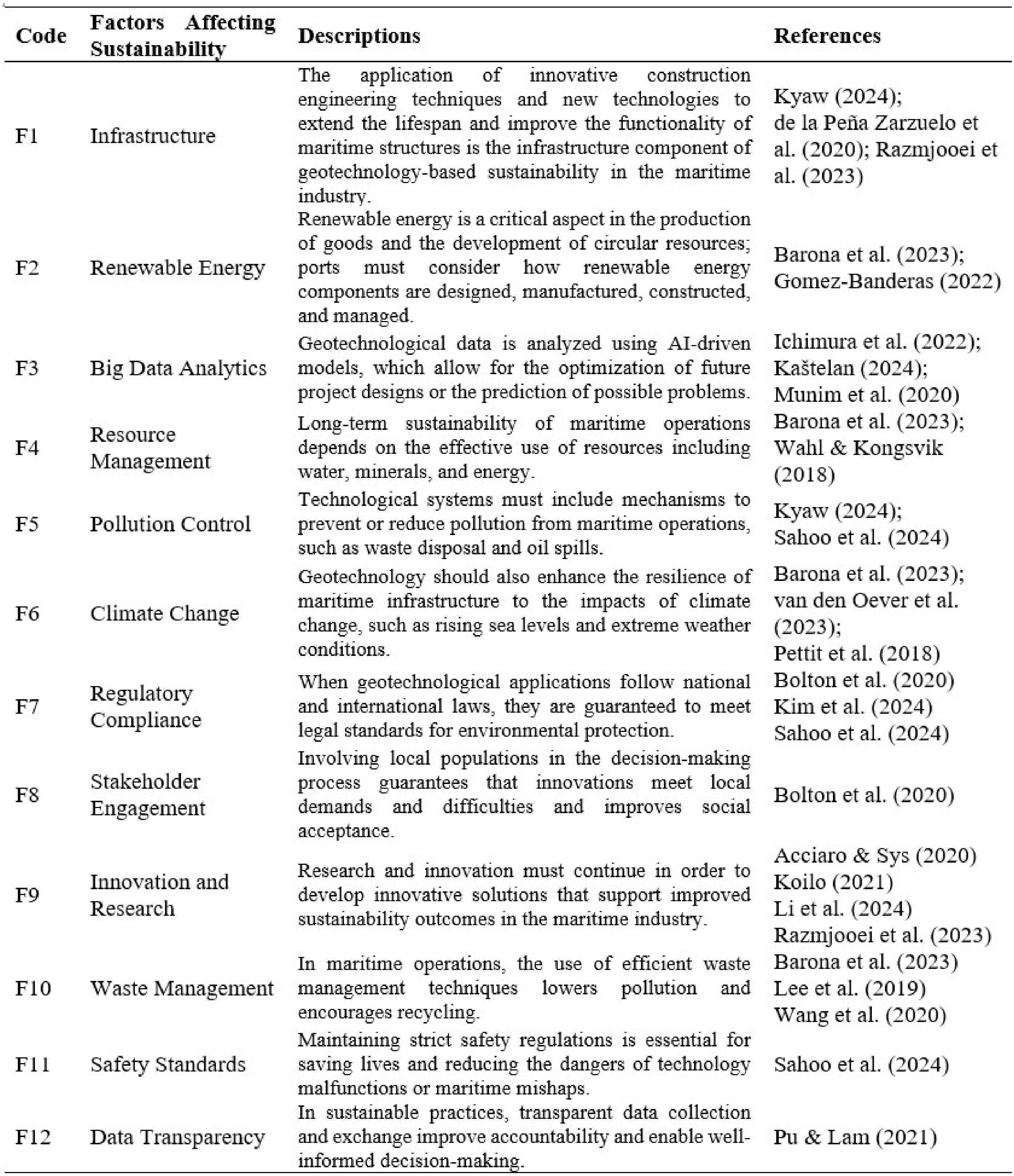
The next step in the ISM approach is to create an initial affordance matrix from the SSIM. This is achieved by following Table 2's substitution instructions and substituting 1 or 0 for the four SSIM symbols (V, A, X, and O). The affordance matrix is then checked for transitivity, a key ISM concept. Transitivity states that if variable X is related to variable Y and variable Y is related to variable Z, then variable X must also be related to variable Z.

After applying transitivity, the updated affordance matrix is obtained (Table 6). The affordance matrix illustrates the driving forces and dependencies of each factor. A factor's driving force is determined by summing the number of factors that it influences (i.e., the number of ones in its row), while its dependency is determined by summing the number of factors that influence it (i.e., the number of ones in its column).

Step 3: Level partitions

Each factor's reachability set and antecedent set are obtained from the Reachability Matrix. The antecedent set consists of the factor and its influencing factors, whereas the reachability set consists of the factor and any additional elements it may affect. The intersection of these two sets is then determined for all factors. The factors whose reachability sets and intersections are identical are assigned to the top level of the ISM hierarchy. These top-level factors are those that do not

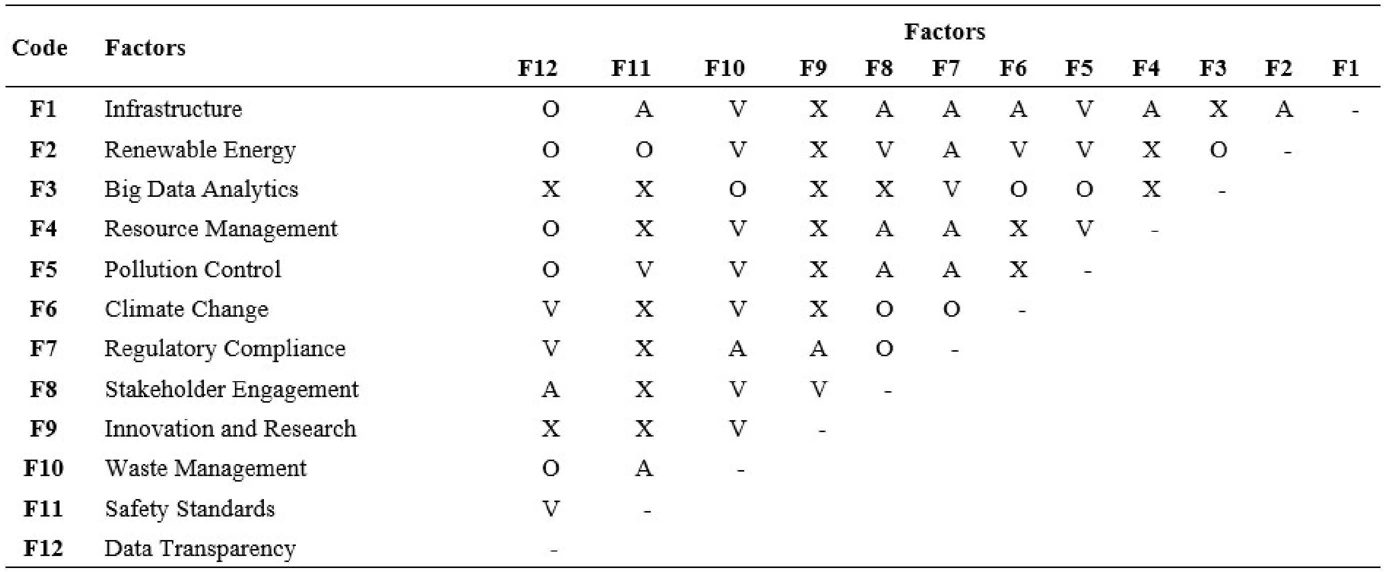
Table 4: Description of selected factors in geotechnology-based sustainability.



Code	Factors Affecting Sustainability	Descriptions	References
F1	Infrastructure	The application of innovative construction engineering techniques and new technologies to extend the lifespan and improve the functionality of maritime structures is the infrastructure component of geotechnology-based sustainability in the maritime industry.	Kyaw (2024); de la Peña Zarzuelo et al. (2020); Razmjooei et al. (2023)
F2	Renewable Energy	Renewable energy is a critical aspect in the production of goods and the development of circular resources; ports must consider how renewable energy components are designed, manufactured, constructed, and managed.	Barona et al. (2023); Gomez-Banderas (2022)
F3	Big Data Analytics	Geotechnological data is analyzed using AI-driven models, which allow for the optimization of future project designs or the prediction of possible problems.	Ichimura et al. (2022); Kaštelan (2024); Munim et al. (2020)
F4	Resource Management	Long-term sustainability of maritime operations depends on the effective use of resources including water, minerals, and energy.	Barona et al. (2023); Wahl & Kongsvik (2018)
F5	Pollution Control	Technological systems must include mechanisms to prevent or reduce pollution from maritime operations, such as waste disposal and oil spills.	Kyaw (2024); Sahoo et al. (2024)
F6	Climate Change	Geotechnology should also enhance the resilience of maritime infrastructure to the impacts of climate change, such as rising sea levels and extreme weather conditions.	Barona et al. (2023); van den Oever et al. (2023); Pettit et al. (2018)
F7	Regulatory Compliance	When geotechnological applications follow national and international laws, they are guaranteed to meet legal standards for environmental protection.	Bolton et al. (2020) Kim et al. (2024) Sahoo et al. (2024)
F8	Stakeholder Engagement	Involving local populations in the decision-making process guarantees that innovations meet local demands and difficulties and improves social acceptance.	Bolton et al. (2020)
F9	Innovation and Research	Research and innovation must continue in order to develop innovative solutions that support improved sustainability outcomes in the maritime industry.	Acciaro & Sys (2020) Koilo (2021) Li et al. (2024) Razmjooei et al. (2023)
F10	Waste Management	In maritime operations, the use of efficient waste management techniques lowers pollution and encourages recycling.	Barona et al. (2023) Lee et al. (2019) Wang et al. (2020)
F11	Safety Standards	Maintaining strict safety regulations is essential for saving lives and reducing the dangers of technology malfunctions or maritime mishaps.	Sahoo et al. (2024)
F12	Data Transparency	In sustainable practices, transparent data collection and exchange improve accountability and enable well-informed decision-making.	Pu & Lam (2021)

Source: Authors.

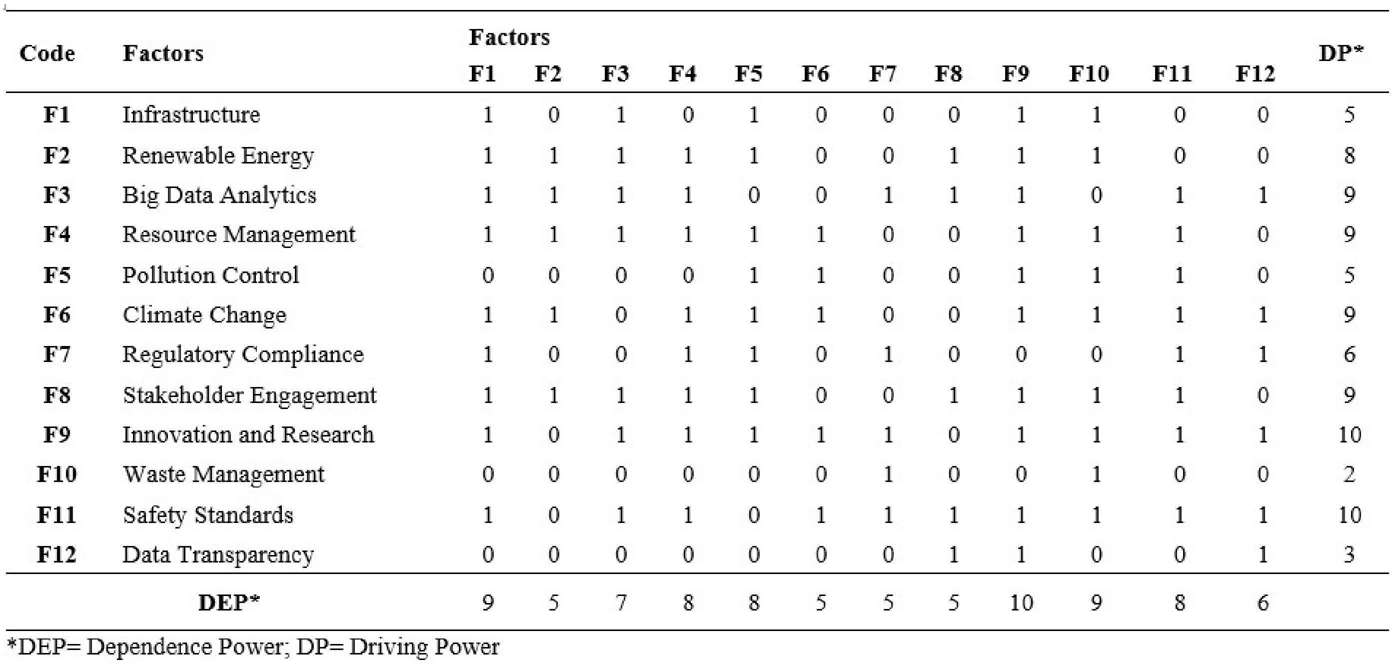
Table 5: Structural Self-Interaction Matrix (SSIM).



Code	Factors	Factors											
		F12	**F11**	**F10**	**F9**	**F8**	**F7**	**F6**	**F5**	**F4**	**F3**	**F2**	**F1**
F1	Infrastructure	O	A	V	X	A	A	A	V	A	X	A	-
F2	Renewable Energy	O	O	V	X	V	A	V	V	X	O	-	
F3	Big Data Analytics	X	X	O	X	X	V	O	O	X	-		
F4	Resource Management	O	X	V	X	A	A	X	V	-			
F5	Pollution Control	O	V	V	X	A	A	X	-				
F6	Climate Change	V	X	V	X	O	O	-					
F7	Regulatory Compliance	V	X	A	A	O	-						
F8	Stakeholder Engagement	A	X	V	V	-							
F9	Innovation and Research	X	X	V	-								
F10	Waste Management	O	A	-									
F11	Safety Standards	V	-										
F12	Data Transparency	-											

Source: Authors.

Table 6: Reachability Matrix.



Code	Factors	Factors												DP*
		F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**	**F12**	
F1	Infrastructure	1	0	1	0	1	0	0	0	1	1	0	0	5
F2	Renewable Energy	1	1	1	1	1	0	0	1	1	1	0	0	8
F3	Big Data Analytics	1	1	1	1	0	0	1	1	1	0	1	1	9
F4	Resource Management	1	1	1	1	1	1	0	0	1	1	1	0	9
F5	Pollution Control	0	0	0	0	1	1	0	0	1	1	1	0	5
F6	Climate Change	1	1	0	1	1	1	0	0	1	1	1	1	9
F7	Regulatory Compliance	1	0	0	1	1	0	1	0	0	0	1	1	6
F8	Stakeholder Engagement	1	1	1	1	1	0	0	1	1	1	1	0	9
F9	Innovation and Research	1	0	1	1	1	1	1	0	1	1	1	1	10
F10	Waste Management	0	0	0	0	0	0	1	0	0	1	0	0	2
F11	Safety Standards	1	0	1	1	0	1	1	1	1	1	1	1	10
F12	Data Transparency	0	0	0	0	0	0	0	1	1	0	0	1	3
	DEP*	9	5	7	8	8	5	5	5	10	9	8	6	

*DEP= Dependence Power; DP= Driving Power

Source: Authors.

Table 7: Level partitioning of reachability matrix.

	Reachability	Antecedent	Intersection	Level
F1	1;3;5;9;10	1;2;3;4;6;7;8;9;11	1;3;9	V
F2	1;2;3;4;5;8;9;10	2;3;4;6;8	2;3;4;8	III
F3	1;2;3;4;7;8;9;11;12	1;2;3;4;8;9;11	1;2;3;4;8;9;11	II
F4	1;2;3;4;5;6;9;10;11	2;3;4;6;7;8;9;11	2;3;4;6;9;11	III
F5	5;6;9;10;11	1;2;4;5;6;7;8;9	5;6;9	V
F6	1;2;4;5;6;9;10;11;12	4;5;6;9;11	4;5;6;9;11	III
F7	1;4;5;7;11;12	3;7;9;10;11	7;11	V
F8	1;2;3;4;5;8;9;10;11	2;3;8;11;12	2;3;8;11	V
F9	1;3;4;5;6;7;9;10;11;12	1;2;3;4;5;6;8;9;11;12	1;3;4;5;6;9;11;12	I
F10	7;10	1;2;4;5;6;8;9;10;11	10	V
F11	1;3;4;6;7;8;9;10;11;12	3;4;5;6;7;8;9;11	3;4;6;7;8;9;11	II
F12	8;9;12	3;6;7;9;11;12	9;12	IV

Source: Authors.

influence any other factors above their level in the hierarchy (Chand et al., 2020).

Once the top-level factors are identified, they are removed from consideration, and the same process is repeated to find the factors at the next level. This iterative process continues until the level of each factor is determined. The results of the level partitioning process indicate that there are 5 levels for the identified drivers, which are shown in Table 7.

Step 4: Developing Digraph

The partition levels from Table 7 are used to create a hierarchical model of geotechnology-based sustainability factors in the maritime industry. To visualize the relationships between the factors, a digraph is constructed. In this process, if the average score for the relationship between factors is lower than a certain threshold, the relationship is removed from the diagram. This step ensures that only significant relationships are included.

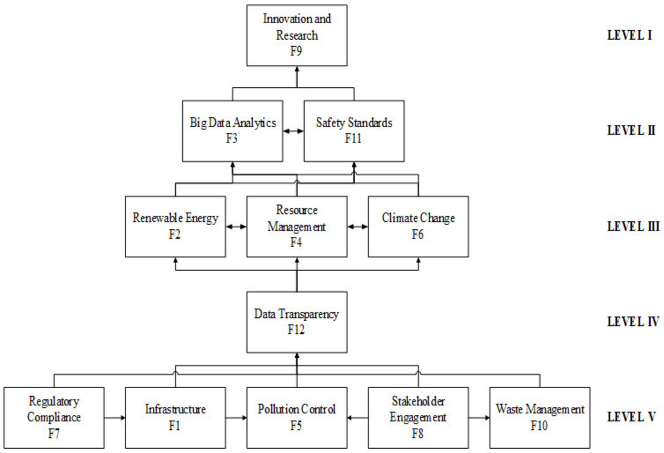
The digraph is then refined by eliminating transitive relationships, as outlined in the ISM methodology (Rakhmadi et al., 2025). Once transitivity is removed, the refined digraph is transformed into the final ISM model. This model illustrates the interdependence of the factors across five hierarchical levels.

Based on the partition levels described above, we constructed a structural hierarchical model as illustrated in Figure 2. In this diagram, the drivers are arranged in a hierarchical structure from Level 1 to Level 5. Drivers at the lower levels influence those at the higher levels. In general, drivers with strong driving power are positioned at the lower levels, while those with high dependence power appear at the higher levels.

4.3. Interaction of Sustainability Factors in the Geotechnology Aspect.

MICMAC analysis was used to examine how sustainability elements interacted with the geotechnology aspect. The driving forces and dependence linkages of geotechnology-based sustainability aspects in the defense sector were investigated using

Figure 2: ISM Model of Geotechnology-Based Sustainability in the Maritime Industry.



Source: Authors.

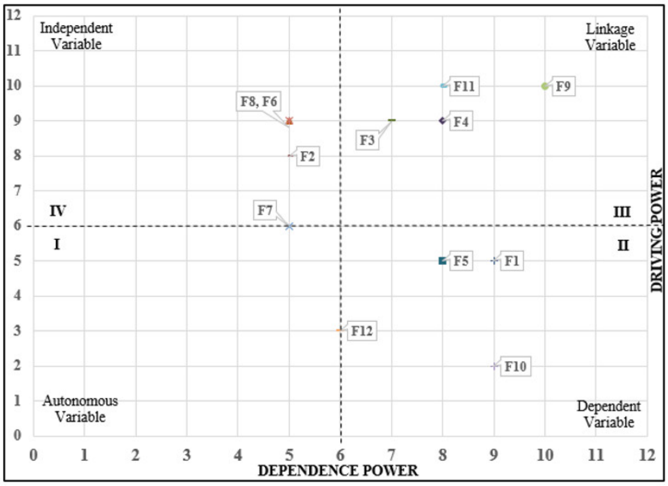
Table 8: Position coordinates of geotechnology - based sustainability in the maritime industries.

Code	Factors	Driving Power (x)	Dependence Power (y)
F1	Infrastructure	9	5
F2	Renewable Energy	5	8
F3	Big Data Analytics	7	9
F4	Resource Management	8	9
F5	Pollution Control	8	5
F6	Climate Change	5	9
F7	Regulatory Compliance	5	6
F8	Stakeholder Engagement	5	9
F9	Innovation and Research	10	10
F10	Waste Management	9	2
F11	Safety Standards	8	10
F12	Data Transparency	6	3

Source: Authors.

this method. The driving power and dependency levels were plotted on the X and Y axes, respectively. Based on the driving and dependency capabilities listed in Table 8, the elements were separated into four groups, as shown in Figure 3: autonomous, driver, linkage, and dependent.

Figure 3: MICMAC Analysis of Geotechnology-Based Sustainability in the Maritime Industry.



Source: Authors.

Cluster 1 – Autonomous Drivers: These drivers exhibit weak driving power and weak dependence. No drivers were identified in this cluster.

Cluster 2 – Dependent Drivers: This cluster is characterized by high dependence and low driving power. The following factors fall within this cluster: Infrastructure (F1), Pollution Control (F5), Waste Management (F10), and Data Transparency (F12).

Cluster 3: Linkage Drivers. These drivers are defined by both high driving and high dependence power. The factors in this cluster include Big Data Analytics (F3), Resource Management (F4), Innovation and Research (F9), and Safety Standards (F11).

Cluster 4 – Driving Drivers: These drivers have strong driving power but low dependence. This cluster comprises Renewable Energy (F2), Climate Change (F6), Regulatory Compliance (F7), and Stakeholder Engagement (F8).

5. Discussion.

The final model of geotechnology-based sustainability factors in the maritime industry was developed through three rounds of Delphi and Interpretive Structural Modeling (ISM). Twelve factors were identified for further analysis, based on expert consensus. Content analysis, using open and axial coding, helped determine the relevant factors from the Delphi method and interviews.

To assure correctness, the expert panel examined the MICMAC data as well as the interpretative structural model. Four of the sixteen criteria were eliminated after analysis revealed high agreement on twelve of them. Climate resilience, biodiversity conservation, and economic viability were not included in the first round since they had no direct bearing on geotechnological sustainability. The extraction-conservation relationship is at odds with sustainability objectives, because geotechnology prioritizes environmental performance and efficiency rather than complete climate resilience (Billon, 2021). Economic viability operates within a different framework, separate from geotechnological innovation.

In the second round, only one thing was taken out: Capacity Building. Building capacity is important for making sustainability practices possible, but it doesn't directly lead to advances in geotechnology. The factors listed point to technologies that can be directly measured or seen through improvements in the environment and operations. This makes capacity building an indirect enabler instead of a stand-alone solution.

In the ISM model, drivers are arranged in a hierarchy from level 1 to level 5. Innovation and Research (F9) is the only driver on Level 1. The convergence of strategy with innovation diffusion and policy offers significant research opportunities (Acciaro & Sys, 2020). Innovation and research integrate essential success factors and incentives, serving a crucial function in attaining sustainable export performance (Rashnodi & Ahmadian, 2023). Initiatives for research and development must address technical challenges and promote advancements in energy and technology efficiency (Sahoo et al., 2024). Infrastructure (F1), Pollution Control (F5), Regulatory Compliance (F7), Stakeholder Engagement (F8), and Waste Management (F10) are the five drivers at Level 5. Port services are improved by infrastructural improvements and technological breakthroughs (Armoo et al., 2020). Seaports and terminals are critical infrastructure because they are important parts of the global supply chain (de la Peña Zarzuelo et al., 2020). Pollution prevention is not the same as pollution control. Pollution prevention makes processes more efficient, while pollution control focuses on treating waste at the source (Johnston Edwards & Walker, 2020). To protect the environment, we need to build waste management infrastructure like recycling centers and advanced wastewater treatment systems (Barona et al., 2023). Long-term success requires infrastructure investment in these sectors as well as advancements in waste management, pollution control, and sustainable development (Rosário & Dias, 2022).

The framework highlights opportunities for geotechnology-enabled sustainability in the maritime industry, but it also offers stakeholders a number of consequences and suggestions. Theoretically, this study offers a novel approach that combines geotechnology with sustainability in the maritime sector to simplify network complexity. This paradigm might promote more studies in maritime risk assessment and geotechnology-driven sustainability. In order to ensure that operations are robust and adhere to international environmental standards, theoretical contributions also assist engineers and policymakers in determining how to take proactive measures toward sustainability. Additionally, the study aids academics in situating their research within the corpus of literature already available on geotechnology-based sustainability in the maritime sector. The most significant research, writers, organizations, concepts, and techniques in this area are also thoroughly reviewed. The maritime sector should embrace geotechnology-driven sustainability to strengthen its competitive advantage despite its challenges. However, the industry must completely comprehend the requirements of geotechnology, including privacy, transparency, scalability, and interoperability, before it can embrace these things.

Conclusions.

Improvements in maritime technology and its use to promote sustainability show a careful but hopeful attitude, driven by the need for efficiency and openness. This study looks at sustainability factors in the maritime industry that are influenced by geotechnology. Twelve of the sixteen suggested factors are mostly agreed upon by experts, according to Delphi data analysis. There were four excluded elements. Infrastructure, renewable energy, big data analytics, resource management, pollution control, climate change, regulatory compliance, stakeholder engagement, innovation and research, waste management, safety standards, and data transparency are the twelve components.

The ISM model says that the driver hierarchy is made up of five levels. Innovation and Research (F9) is the only driver at Level 1. At Level 5, there are five drivers: Infrastructure (F1), Pollution Control (F5), Regulatory Compliance (F7), Stakeholder Engagement (F8), and Waste Management (F10). There are four types of drivers: autonomous, driver, linkage, and dependency. These are based on how they work and how they depend on each other. This study identifies no drivers categorized as autonomous. Four drivers are classified as linkages, dependencies, and drivers, underscoring the significance of all elements within the model.

There are a few problems with the research. First, the research was limited in depth because of time constraints. This shows that more in-depth field studies are needed to fully understand how geotechnology-based sustainability affects the maritime sector. Second, most of the data comes from companies in the maritime industry, which means that future research could look into other fields, like tourism and manufacturing. Third, the study focuses solely on the establishment of hierarchical relationships among geotechnology-based sustainability factors pertinent to maritime operations, thereby allowing for subsequent investigations into resource-based sustainability or geotechnology-based resilience. Last but not least, the ISM model used in this study is predicated on expert judgments, which may be skewed because they already have preconceived notions about what ought to occur. Alternative qualitative or quantitative approaches, such as Data Envelopment Analysis (DEA) or Structural Equation Modeling (SEM), may be used in later studies to validate and improve the model.

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References.

Acciaro, M., & Sys, C. (2020). Innovation in the maritime sector: aligning strategy with outcomes. Maritime Policy and Management, 47(8), 1045–1063. https://doi.org/10.1080/03088839.2020.1737335.

Ali, P. R., Machfud, M., Sukardi, S., Noor, E., & Purnomo, D. (2023). Indonesian agroindustry business agility: Enablers and challenges in the poultry industry based on ISM model. Heliyon, 9(6), e16808. https://doi.org/10.1016/j.heliyon.2023.e16808.

Armoo, A. K., Franklyn-Green, L. G., & Braham, A. J. (2020). The fourth industrial revolution: a game-changer for the tourism and maritime industries. Worldwide Hospitality and Tourism Themes, 12(1), 13–23. https://doi.org/10.1108/WHATT-10-2019-0063.

Barona, J., Ballini, F., & Canepa, M. (2023). Circular developments of maritime industrial ports in Europe: a semi-systematic review of the current situation. In Journal of Shipping and Trade (Vol. 8, Issue 1). Springer Nature Singapore. https://doi.org/10.1186/s41072-023-00153-w.

Ben Ruben, R., Rajendran, C., Saravana Ram, R., Kouki, F., Alshahrani, H. M., & Assiri, M. (2023). Analysis of barriers affecting Industry 4.0 implementation: An interpretive analysis using total interpretive structural modeling (TISM) and Fuzzy MICMAC. Heliyon, 9(12), e22506. https://doi.org/10.1016/j.heliyon.2023.e22506.

Bhutani, R. (2019). Geopolitics to Geo-economics to the new Era of Geo-technology.Billon, P. Le. (2021). Crisis conservation and green extraction: biodiversity offsets as spaces of double exception. Journal of Political Ecology, 28(1), 1–25. https://doi.org/10.2458/JPE.2991.

Bolton, D., Landells, T., & Roberts, B. (2020). Sustainable Governance and Responsive Regulation: The Higher Education Sector and Maritime Industry in Australia. Journal of Sustainability Research, 2(3). https://doi.org/10.20900/jsr20200023.

Chand, P., Thakkar, J. J., & Ghosh, K. K. (2020). Analysis of supply chain sustainability with supply chain complexity, inter-relationship study using delphi and interpretive structural modeling for Indian mining and earthmoving machinery industry. Resources Policy, 68(May), 101726. https://doi.org/10.1016/j.resourpol.2020.101726.

Coimbra, M. R., Almeida-Leite, C. M., de Faria-Fortini, I., Christo, P. P., & Scalzo, P. L. (2021). King's Parkinson's Disease Pain Scale (KPPS): Cross-cultural adaptation to Brazilian Portuguese and content validity. Clinical Neurology and Neurosurgery, 208(March). https://doi.org/10.1016/j.clineuro.2021.106815.

de la Peña Zarzuelo, I., Freire Soeane, M. J., & López Bermúdez, B. (2020). Industry 4.0 in the port and maritime industry: A literature review. Journal of Industrial Information Integration, 20, 100173. https://doi.org/10.1016/j.jii.2020.100173.

Firmanto, B. A., Bandono, A., Purnomo, J., Krisdianto, E., & Susilo, A. K. (2024). Key Factors Of Cyber Threat In Digital Navigation Using Delphi-ISM Approach. Journal of Maritime Research, XXI(III), 209–218.

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.

Gomez-Banderas, J. (2022). Marine Natural Products: A Promising Source of Environmentally Friendly Antifouling Agents for the Maritime Industries. Frontiers in Marine Science, 9 (February), 1–7. https://doi.org/10.3389/fmars.2022.858757.

Grober, U. (2014). The discovery of sustainability: The genealogy of a term. In Theories of sustainable development (pp. 6–15). Routledge.

Hajian, M., & Kashani, S. J. (2021). Evolution of the concept of sustainability. From Brundtland Report to sustainable development goals. In Sustainable resource management (pp. 1–24). Elsevier.

He, Z., & Elhami Khorasani, N. (2022). Identification and hierarchical structure of cause factors for fire following earthquake using data mining and interpretive structural modeling. Natural Hazards, 112(1), 947–976. https://doi.org/10.1007/s11069-022-05214-0.

Ichimura, Y., Dalaklis, D., Kitada, M., & Christodoulou, A. (2022). Shipping in the era of digitalization: Mapping the future strategic plans of major maritime commercial actors. Digital Business, 2(1), 100022. https://doi.org/10.1016/j.digbus.2022.100022.

Jaffrelot, C., & Louédin, P. (2022). The-geotechnological-competition-between-the-US-and-China-is-a-threat-to-Indo-Pacifics-security-re?duit.pdf. Paris School of International Affairs.

Jannat, F., Khorasani-Zavareh, D., Mir-Aghazadeh-Attari, J., Allahbakhshi, K., & Mohebbi, I. (2020). Designing a model for organizing volunteer personnel in disasters and emergencies in Tehran's hospitals: an integrated approach of Fuzzy Delphi and interpretative structure modeling (ISM). Natural Hazards, 103(2), 1807–1821. https://doi.org/10.1007/s11069-020-04055-z.

Johnston Edwards, S., & Walker, T. R. (2020). An overview of Canada's National Pollutant Release Inventory program as a pollution control policy tool. Journal of Environmental Planning and Management, 63(6), 1097–1113. https://doi.org/10.1080/09640568.2019.1634525.

Kaštelan, N., Vidan, P., Assani, N., & Miličević, M. (2024). Digital Horizon: Assessing Current Status of Digitalization in Maritime Industry. Transactions on Maritime Science, 13(1). https://doi.org/10.7225/toms.v13.n01.w13.

Kim, H., Xiao, Z., Zhang, X., Fu, X., & Qin, Z. (2024). Rethinking Blockchain Technologies for the Maritime Industry: An Overview of the Current Landscape. Future Internet, 16(12), 1–19. https://doi.org/10.3390/fi16120454.

Koilo, V. (2021). Evaluation of R&D activities in the maritime industry: Managing sustainability transitions through business model. Problems and Perspectives in Management, 19(3), 230–246. https://doi.org/10.21511/ppm.19(3).2021.20.

Kumar, S., Raut, R. D., Narwane, V. S., Narkhede, B. E., & Muduli, K. (2022). Implementation barriers of smart technology in Indian sustainable warehouse by using a Delphi-ISM-ANP approach. International Journal of Productivity and Performance Management, 71(3), 696–721. https://doi.org/10.1108/IJPPM-10-2020-0511.

Kyaw, A. Y. (2024). Application of Advanced Technology on Transport Ships as a Technological Revolution in the Maritime Industry. Maritime Park Journal of Maritime Technology and Society, 3(June), 1–7. https://doi.org/10.62012/mp.v3i2.35384.

Lee, P. T. W., Kwon, O. K., & Ruan, X. (2019). Sustainability challenges in maritime transport and logistics industry and its way ahead. Sustainability (Switzerland), 11(5), 1–9. https://doi.org/10.3390/su11051331.

Li, X., Zhou, Y., & Yuen, K. F. (2024). Blockchain implementation in the maritime industry: critical success factors and strategy formulation. Maritime Policy and Management, 51(2), 304–322. https://doi.org/10.1080/03088839.2022.2119614.

Mahran, G. S. K., Tolba, A. A., Abbas, M. S., & Thabet, A. M. A. (2021). Development and validation of a daily assessment tool for critically ill patients. Nursing in Critical Care, September, 1–7. https://doi.org/10.1111/nicc.12717.

Moradi, E., Ehsani, M., Saffari, M., & Norouzi Seyed Hosseini, R. (2023). How can destination competitiveness play an essential role in small island sports tourism development? Integrated ISM-MICMAC modelling of key factors. Journal of Hospitality and Tourism Insights, 6(3), 1222–1252. https://doi.org/10.1108/JHTI-03-2022-0118.

Munasinghe, N. L., O'Reilly, G., Cameron, P., De Alwis, S., & Herath, H. D. B. (2023). Developing a hospital disaster preparedness evaluation tool for Sri Lanka - A modified Delphi study. International Journal of Disaster Risk Reduction, 95(July), 103866. https://doi.org/10.1016/j.ijdrr.2023.103866.

Munim, Z. H., Dushenko, M., Jimenez, V. J., Shakil, M. H., & Imset, M. (2020). Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions. Maritime Policy and Management, 47(5), 577–597. https://doi.org/10.1080/03088839.2020.1788731.

Nedelcu, M.-R. (2024). The Rise of Geotechnology: A Paradigm Shift from Geopolitics and Geoeconomics in the Context of Industry 4.0. Proceedings of the International Conference on Business Excellence, 18(1), 1979–1988. https://doi.org/10.2478/picbe-2024-0167.

Okumus, D., Gunbeyaz, S. A., Kurt, R. E., & Turan, O. (2023). Towards a circular maritime industry: Identifying strategy and technology solutions. Journal of Cleaner Production, 382 (November 2022), 134935. https://doi.org/10.1016/j.jclepro.2022.134935.

Pettit, S., Wells, P., Haider, J., & Abouarghoub, W. (2018). Revisiting history: Can shipping achieve a second socio-technical transition for carbon emissions reduction? Transportation Research Part D: Transport and Environment, 58, 292–307. https://doi.org/10.1016/j.trd.2017.05.001.

Pu, S., & Lam, J. S. L. (2021). Blockchain adoptions in the maritime industry: a conceptual framework. Maritime Policy and Management, 48(6), 777–794. https://doi.org/10.1080/03088839.2020.1825855.

Qureshi, K. M., Mewada, B. G., Alghamdi, S. Y., Almakayeel, N., Mansour, M., & Qureshi, M. R. N. (2022). Exploring the Lean Implementation Barriers in Small and Medium-Sized Enterprises Using Interpretive Structure Modeling and Interpretive Ranking Process. Applied System Innovation, 5(4), 1–20. https://doi.org/10.3390/asi5040084.

Rakhmadi, A. T. I., Khusaini, M., Puspitawati, D., Aminuddin, M. F., & Susilo, A. K. (2025). Exploring Key Factors of Coastal Defense System from Military Perspective in Surabaya Region using Delphi and Interpretive Structural Modeling. Journal Of Maritime Research, XXII(I), 35–49.

Rashnodi, A., & Ahmadian, A. (2023). Export strategy in the context of coronavirus (COVID-19), Identifying drivers and critical success factors, Based on the study of active firms in Iranian ports and maritime .... International Journal Of Coastal, Offshore And ..., 8(1). https://www.ijcoe.org/article_167521.html.

Rathore, B., Gupta, R., Biswas, B., Srivastava, A., & Gupta, S. (2022). Identification and analysis of adoption barriers of disruptive technologies in the logistics industry. International Journal of Logistics Management, 33(5), 136–169. https://doi.org/10.1108/IJLM-07-2021-0352.

Razmjooei, D., Alimohammadlou, M., Ranaei Kordshouli, H. A., & Askarifar, K. (2023). Industry 4.0 research in the maritime industry: a bibliometric analysis. In WMU Journal of Maritime Affairs (Vol. 22, Issue 0123456789). Springer Berlin Heidelberg. https://doi.org/10.1007/s13437-022-00298-8.

Rosário, A. T., & Dias, J. C. (2022). Sustainability and the Digital Transition: A Literature Review. Sustainability (Switzerland), 14(7), 1–18. https://doi.org/10.3390/su14074072.

Ruggerio, C. A. (2021). Sustainability and sustainable development: A review of principles and definitions. Science of the Total Environment, 786, 147481. https://doi.org/10.1016/j.scitotenv.2021.147481.

Sahoo, S. K., Choudhury, B. B., & Dhal, P. R. (2024). Exploring the Role of Robotics in Maritime Technology: Innovations, Challenges, and Future Prospects. Spectrum of Mechanical Engineering and Operational Research, 1(1), 159–176. https://doi.org/10.31181/smeor11202414.

Slack, B. (2010). Battening down the hatches: How should the maritime industries weather the financial tsunami? Research in Transportation Economics, 27(1), 4–9. https://doi.org/10.1016/j.retrec.2009.12.002.

T.Vinila. (2024). Global Sustainability. Global Sustainability, 6(04), 63–78. https://doi.org/10.4324/9780203166260Thiel, T. (2017). Turnkey tyranny? Struggles for a new digital order. Springer.

Ullah, S., Ahmad, N., Khan, F. U., Badulescu, A., & Badulescu, D. (2021). Mapping interactions among green innovations barriers in manufacturing industry using hybrid methodology: Insights from a developing country. International Journal of Environmental Research and Public Health, 18(15). https://doi.org/10.3390/ijerph18157885.

van den Oever, F., Fjeld, M., & Sætrevik, B. (2023). A Systematic Literature Review of Augmented Reality for Maritime Collaboration. International Journal of Human-Computer Interaction, 0(0), 1–16. https://doi.org/10.1080/10447318.2023.2209838.

Venkatesh, V. G., Rathi, S., & Patwa, S. (2015). Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling. Journal of Retailing and Consumer Services, 26, 153–167. https://doi.org/10.1016/j.jretconser.2015.06.001.

Wahl, A. M., & Kongsvik, T. (2018). Crew resource management training in the maritime industry: a literature review. WMU Journal of Maritime Affairs, 17(3), 377–396. https://doi.org/10.1007/s13437-018-0150-7.

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 entrepreneurship perspective. Transportation Research Part D: Transport and Environment, 78, 102173. https://doi.org/10.1016/j.trd.2019.11.002.

Warfield, J. N. (1974). Developing Subsystem Matrices in Structural Modeling. IEEE Transactions on Systems, Man and Cybernetics, SMC-4(1), 74–80. https://doi.org/10.1109/TSMC.1974.5408523.

Wong, J. (2020). Digital Divide: Geotechnology, Politics and the International System. In Graduate School of Public and International Affairs (Vol. 12, Issue 2). https://talenta.usu.ac.id/politeia/article/view/3955.

Wrublack, S. C., Mercante, E., Prudente, V. H. R., Silva, J. L. G., Boas, M. A. V., & Oldoni, L. V. (2015). Geotechnologies and multivariate statistics applied to water resources management in a predominantly agricultural watershed. Journal of Food, Agriculture and Environment, 13(2), 201–209.

Wu, P., Chen, Q., Chen, Y., Chen, S., & Zou, J. (2023). ISM-MICMAC based safety risk sources analysis and control measures for underground engineering of urban rail transit projects. Journal of Engineering Research, March, 100076. https://doi.org/10.1016/j.jer.2023.100076.

Yang, G. (2014). The Return of Ideology and the Future of Chinese Internet Policy. Critical Studies in Media Communication, 31(2), 109–113. https://doi.org/10.1080/15295036.2014.913803.

Yusup, M. F. Bin. (2023). Sustainable Shipping Practices: A Review of Environmental Initiatives in the Maritime Industry. Maritime Park Journal of Maritime Technology and Society, 2(October), 140–142. https://doi.org/10.62012/mp.v2i3.32647.