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Escuela Técnica Superior de Náutica
c/ Gamazo nº1, 39004 SANTANDER
Telfno (942) 201362; Fax (942) 201303
e-mail: info.jmr@unican.es
http://www.jmr.unican.es

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THE INFLUENCE OF THE EXTERNAL SALINITY IN THE OSMOTIC BLISTERING ON MARINE COATINGS IN TOTAL IMMERSION

R. García[1,2], I. Irastroza[1,3], A. Castaños[1,4] and F. Cayuela[1,5]

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Abstract

The use of anticorrosive paints to protect the hulls of ships is essential. These coatings are deteriorating because they are completely submerged. One phenomenon that appears in the degradation of the coating is blistering. This type of blistering has two origins, the cathode and osmotic. The cathodic blistering occurs as a result of the cathodic reaction of corrosion process, that takes place on the metallic substrate. The osmotic blistering is caused by the difference of concentration of the solutions (pollution solution interface and external). Applying these coatings on nonmetallic substrates would result in blistering, therefore, of osmotic origin. This article presents a study in plastic surfaces painted with chlorinated rubber pigmented with iron oxide. These were contaminated with NaCl at the interface substrate / paint and immersed in water with different (salt concentrations) salinities in order to recreate the various salinities of sea water which can be exposed the ship's hull.

The objective of this work is to analyze the influence of external salinity on the emergence of such blistering.

Key words: Osmotic blistering, interface contamination, chlorinated rubber coating.

[1]Professor E.T.S. de Náutica y Máquinas Navales, María Díaz de Haro 68, 48920 Portugalete Bizkaia (Spain). [2]Jefe de Máquinas. Corresponding autor: E-mail address cnpgaber@lg.ehu.es, Tel. 946014841, Fax. 946017700. [3]Jefe de Máquinas. E-mail address: cnpirhei@lg.ehu.es, Tel. 946014846, Fax. 946017700. [4]E-mail address: ompcaura@lg.ehu.es, Tel. 946014877, Fax. 946017700. [5]E-mail address: fernando.cayuela@ehu.es, Tel. 406014793, Fax. 946017700).

INTRODUCTION

One of the phenomena of degradation in the marine paintings in conditions of total immersion is the blistering. The blistering, however, doesn't have an only origin. Funke said that the formation of blisters may be due to four causes (Funke, 1981):

1. The inclusion or formation of gases (Van Laar,1961).
2. The volume's expansion of the coating film (Brunt,1964; James,1960).
3. The osmotic processes originated by the presence of soluble pollutants in the interface coating / substrate (Bullet, Rudram,1961).
4. Electroendosmotic effect (Berendsen, 1989).

It would be necessary to add to that exposed two causes:

5. Vapours or liquids in the interface.
6. The permeability of the coating films.

Osmosis can be defined as the unidirectional diffusion of water and other solvents through a semipermeable membrane. In the beginning, could only cross the membrane solvent, although some authors suggest that most of the paint films may allow the diffusion of inorganic salts such as chlorides and sulfates.

In this process, the solvent passes from low concentration solution to the most concentrated, through the paint film which lies between the two solutions. The osmotic flow will continue until the concentrations of the two solutions are equal, or until it reaches the maximum pressure that the membrane can withstand. . The osmotic blistering occurs as a result of increased osmotic pressure in the area that initially had higher concentration of solute, the membrane bending to increase the volume of this area, thus reducing the pressure.

The factors necessary to bring the phenomenon of osmosis are:

1. A solution containing salts.
2. A semipermeable membrane (painting film).
3. A source of solvent (the water).
4. An impermeable substrate (steel hull of the ship or methacrylate).

The combination of these four factors often occurs in the hulls of ships, because the painting operations are performed in the vicinity of the sea. This causes the salt particles are attached to the hull surface In making the painting, this substrate contaminated with salts be covered with a layer of paint that will act as a semipermeable membrane. When the ship is in the sea, the underwater hull is submerged in water with some degree of salinity. By having different salt concentrations of seawater and the interface is produced by the process described above, resulting in blistering of the paint.

The aim of this article is the analysis of the osmotic blistering and the influence that the contamination interface has in its appearance. In this study we have used acrylic surfaces, which ensures that everything is osmotic blistering.

This work is part of a wider project that is carrying out for the authors about the mechanisms of osmotic and cathodic blistering of marine paintings in continuous immersion that is carried out in the University of the Basque Country.

EXPERIMENTAL

The testing procedure carried out in this study consisted of the measure of the degree of blistering generated by osmosis in plastic specimens. In order to generate the osmotic process, the interface substrate / paint was contaminated with 500 mg/m^2 Cl^-. We considered the following parameters to observe its influence:

1. External NaCl concentration: the specimens were immersed in 8 NaCl solutions: 0 – 5 – 10 – 20 – 25 – 30 – 35 and 40 g/l (NaCl), simulating different concentrations of seawater.
2. Coating thickness: thickness of 50, 100 and 150 µm.
3. Time of exposure in these conditions twelve months and periodic inspections during this time.

The total number of specimens used for this research was 48, that is, since two specimens were tested for each of the 24 possible combinations. As both sides were used for each specimen, the total number of test surfaces was 96.

The specimens consisted of 12 x 8 cm pieces of plastic. The specimens were cleaned and the substrate/coating interface was contaminated with 500 mg/m^2 Cl^-.

After these operations, the specimens were painted by means of a special tool, able to provide the uniform thickness required in each case: 50, 100 and 150 µm.

Once the specimens were prepared, they were placed into 8 plastic boxes, containing the above mentioned external solutions. They were exposed in these conditions at 25°C and continuous air flux during 12 months.

During this time, periodic visual inspections were conducted to assess the degree of osmotic blistering presenting the specimens. The ASTM D-714 Standard was used to classify the size and density of blisters (ASTM, 1987). Different levels of blistering are established in this Standard, as follows:

1. Size: 8 (very small blisters), 6 (small blisters), 4 (big blisters) and 2 (very big blisters)
2. Density of blistering: F (very few density), M (medium density), MD (medium dense) and D (much density)

After sorting the size and density of blisters, the photographs were taken of the most representative examples.

RESULTS

Figure 1 shows the evolution with time of blistering during 12 months exposure, in total immersion conditions, with 8 NaCl concentrations. As above mentioned, in

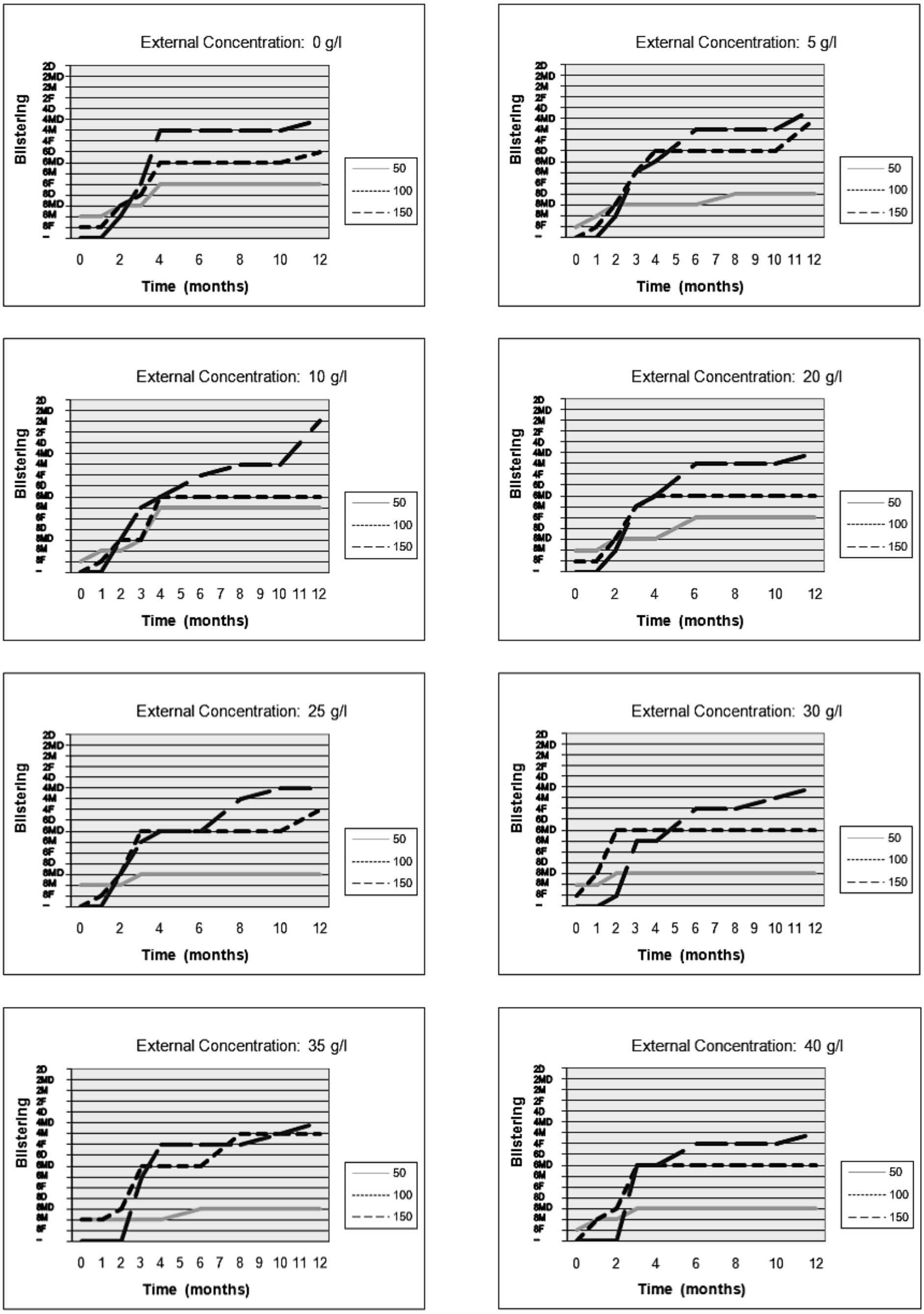

Figure 1: Variation of blistering, according to ASTM D-714, throughout time / *Interface contamination:* 500 mg/m^2 Cl^-.

all the cases, the substrate/coating contamination was 500 mg/m^2 Cl^-. The lines showed in each graph represent the coating thickness (50, 100 and 150 µm).

Besides, the sequence of photographs showed in figures 2 and 3 represent the evolution of blister formation throughout 12 months in specimens with different levels of the external salinity and coating thickness of 100 and 150 µm.

As a first result of this study, the blistering appear in all the tested specimens. This blistering process begins at very early ages.

The blistering starts before specimens containing paint thinner.

The blisters size increases with the time.

The influence of the external salinity is not significant in the blistering (with high level of substrate/coating contamination).

The blistering process begins first in the specimens of 50µm of coating thickness, later in those of 100 µm and lastly in those of 150µm.

The size of the bladders taken place in the specimens of 50 µm is smaller than those of 100 and 150 µm.

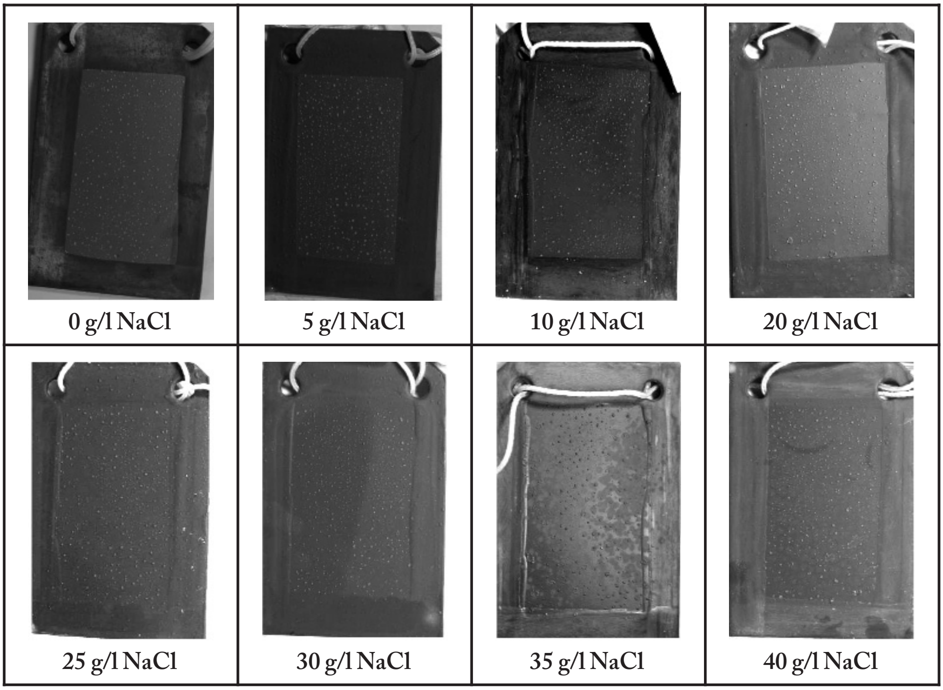

Figure 2: *Coating thickness:* 100µm / *Time:* 12 months / *Interface contamination:* 500 mg/m^2 Cl^-.

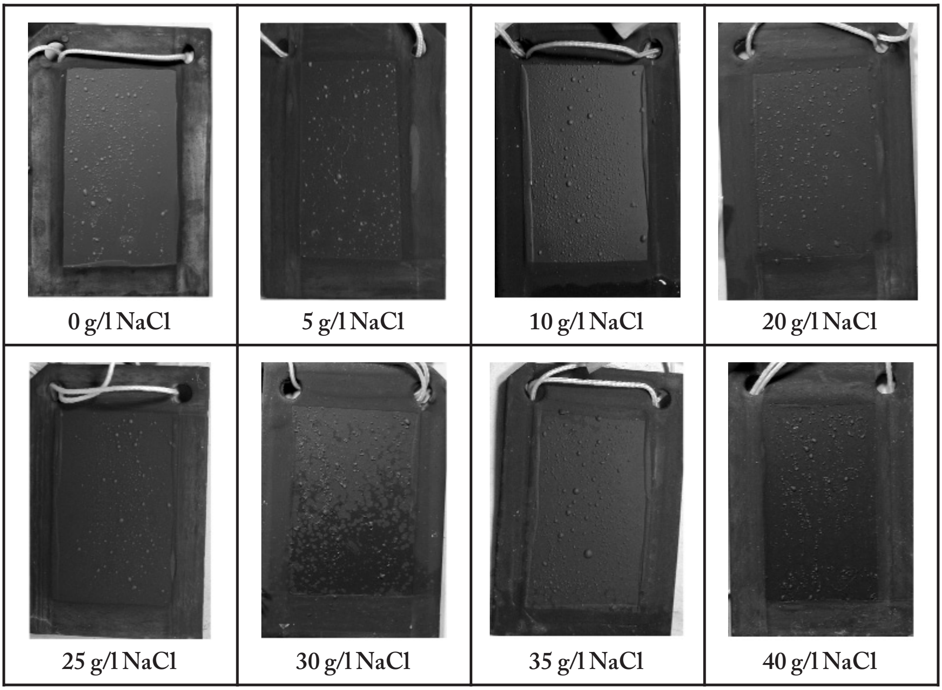

Figure 3: *Coating thickness:* 150μm / *Time:* 12 months / *Interface contamination:* 500 mg/m^2 Cl^-.

DISCUSSION

The blistering process appear in all the specimens with 500 mg/m^2 Cl^-. The specimens are made of plastic, therefore this blistering is due to osmotic processes. The water from external solutions (more diluted than interface) comes into the interface through the coating film, trying to make equal both concentrations.

The blistering process begins before in the specimens of 50 μm of thickness because it is more permeable. The increment of the coating thickness slows the beginning of the blistering process.

In the osmotic blistering process, the solvent, diffuses from the most concentrated solution to the most diluted, passing through the coating film placed between both solutions. The osmotic flow continues until both solutions have reached the same concentration. The blisters will grow while this process continues or the coating film is able to support the osmotic pressure.

In the osmotic blistering process (with high level of substrate/coating contamination) the influence of the external salinity is not significant.

The effect of the coating thickness is not very significant, although in this experiment, the blisters specimens of 50 μm are smaller than in those of 100 and 150 μm.

The results of adhesion test according to ASTM D 4541-85, demonstrated that the adhesive force is greater in the test specimens of 50 μm of thickness that in those of 100 μm and 150 μm.

CONCLUSIONS

1. The osmotic blistering process, in chlorinated rubber paints pigmented with iron oxide with high level of contamination on interface, is not highly influenced by the salinity of the external solution.
2. The coating thickness increased, only delays slightly the onset of the blistering process.
3. The blisters increase in size over time.
4. The osmotic blistering process (with high level of substrate/coating contamination) begins at very early ages.
5. The effect of coating thickness on the osmotic blistering process seems not to be very significant. (In this experiment, the blisters specimens of 50 μm are smaller than in those of 100 and 150 μm because the adhesive force is greater).

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INFLUENCIA DE LA SALINIDAD EXTERIOR EN EL AMPOLLAMIENTO DE PINTURAS MARINAS EN INMERSIÓN TOTAL

Resumen

El uso de las pinturas anticorrosivas para proteger los cascos de los buques es imprescindible. Estas pinturas se deterioran debido a que se encuentran totalmente sumergidas. Uno de los fenómenos que aparece en el deterioro de las pinturas es el ampollamiento. Este tipo de ampollamiento tiene dos orígenes, el catódico y el osmótico. El ampollamiento catódico se produce como consecuencia de la reacción catódica del proceso de corrosión que tiene lugar sobre el substrato metálico. El ampollamiento osmótico tiene su origen en la diferencia de concentración de las disoluciones (contaminación interfase y disolución exterior). Si aplicamos estas pinturas sobre substratos no metálicos el ampollamiento resultante será, por tanto, de origen osmótico.

En este artículo se presenta un estudio realizado en probetas de metacrilato pintado con clorocaucho pigmentado con óxido de hierro. Estas se contaminaron con ClNa en la interfase substrato/pintura y se sumergieron en agua con diferentes (concentraciones de sal) salinidades con el fin de recrear las variadas salinidades del agua de mar a las que puede estar expuesto el casco del buque.

El objeto del estudio fue analizar la influencia que tiene la salinidad exterior en la aparición de este tipo de ampollamiento.

METODOLOGÍA

La ósmosis puede definirse como la difusión unidireccional de agua y otros disolventes a través de una membrana semipermeable. En el principio, sólo el disolvente podría atravesar la membrana, aunque algunos autores sugieren que la mayoría de las películas de pintura pueden permitir la difusión de sales inorgánicas, como los cloruros y sulfatos.

En este proceso, el disolvente pasa de la solución con menor concentración a la más concentrada, atravesando la película de pintura que se halla entre las dos disoluciones. El flujo osmótico continuará hasta que las concentraciones de las dos disoluciones se igualen, o hasta que se alcanza la presión máxima que la membrana puede soportar. El ampollamiento osmótico se produce como consecuencia del aumento de presión osmótica en la zona que inicialmente tenía mayor concentración de soluto, curvando la membrana para aumentar el volumen de esta zona, disminuyendo así la presión.

Los factores necesarios para que aparezca el fenómeno de la ósmosis son los siguientes:

1. Una disolución que contenga sales.
2. Una membrana semipermeable (la capa de pintura).

3. Una fuente de disolvente (el agua).
4. Un substrato impermeable (el acero del casco del buque o la placa de metacrilato).

Para este estudio se han usado probetas de metacrilato de 120 x 80 mm. y de 1,5 mm. de espesor. Estas fueron lijadas con el fin de mejorar la adherencia del metacrilato y limpiadas escrupulosamente. Se contaminó la intercara substrato/pintura con 500 mg/m^2 de Cl^-.

Los parámetros de este estudio son los siguientes:

1. Concentración exterior NaCl: las probetas se sumergieron en 8 concentraciones de NaCl de: 0 – 5 – 10 – 20 – 25 – 30 – 35 y 40 g/l NaCl simulando las diferentes concentraciones del agua de mar.
2. Espesor del recubrimiento: 50, 100 y 150 µm de espesor.
3. Tiempo de la exposición en estas condiciones, doce meses de exposición, e inspecciones periódicas durante este tiempo.

El número total de probetas usadas en este estudio fue de 48, ya que se ensayaron dos probetas para cada una de las 24 posibles combinaciones. Como se usaron las dos caras de cada probeta el número total de superficies de ensayo fue de 96.

Una vez listas las probetas, éstas fueron introducidas en 8 cubetas de plástico que contenían las disoluciones exteriores anteriormente citadas. Manteniéndose estas soluciones durante todo este estudio (12 meses) en condiciones de 25°C y con aireación constante.

Durante este tiempo se realizaron inspecciones visuales periódicas para evaluar el grado de ampollamiento osmótico que presentaban las probetas, usando la Norma A.S.T.M. D-714.

CONCLUSIONES

1. La salinidad de la disolución exterior no influye en gran medida en el ampollamiento de las pinturas de clorocaucho pigmentado con óxido de hierro con alto nivel de contaminación en la intercara substrato/pintura.
2. El aumento del espesor de la pintura sólo retarda el comienzo del ampollamiento.
3. El tamaño de las ampollas aumenta con el tiempo.
4. El ampollamiento (con alto nivel de contaminación en la intercara substrato/pintura) comienza a edades tempranas.
5. La influencia del espesor de pintura no es muy significante. (En este experimento las ampollas aparecidas en las probetas de 50 µm son más pequeñas que las de 100 y 150 µm., debiéndose esto a la menor fuerza de adhesión al substrato de las capas de pintura de 100 y 150 µm espesor).

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TROUBLESHOOTING OF MARINE STEAM TURBO ELECTRO GENERATORS USING ENGINE CONTROL ROOM SIMULATOR

D. Gourgoulis[1]

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Abstrac

The aim of the present study is to examine the daily operation of steam - turbo engine driven electro generators used in maritime engineering for the auxiliary electrical power supply system of ship on real time operation and under malfunctions. On the ship, the preferred mode of operation is with shaft generator as base generator, the turbo generator as an auxiliary generator and with diesel generators in auto operation as stand by generators. Turbo generator modelled as high speed turbine with all vital subsystems such as rpm governor, lubrication oil and steam system with condenser. The research study attempts to make failure analysis and besides to provide solutions for real operating problems. The use of simulator under abnormal conditions helps the instructor and students to understand better the process while at the same time contributes significantly to the development of team spirit and enhances mutual respect and cooperation among to many job functions in the plant.

Key words: Engine Room Simulator, Turbo Generator, Malfunctions, Human factor

INTRODUCTION

The International Maritime Organization (S.T.C.W., 1995) has a key role to play in the successful implementation of new technology at sea. In line, with current policies on risk management and human factors, it will be advisable to research the full

[1] Professor Merchant Marine Academy of Makedonia, e-mail: gourgoulis@ath.forthnet.gr, Tel. 2310855504, Fax. 2392033416, Nea Michaniona, 57004 Nea Michaniona (Greece).

long-term effects of the introduction of each new system on the whole working environment, taking into account parameters such as the system design, maintenance, reliability and training. Besides, on board technology must be friendly, must leave humans in control and must not isolate the user from the outside environment.

One of the main purposes of computer simulation is to imitate the operations of real life systems or processes. The advent of bridge and engine room simulators and their use as modern research tools, now, allows us to test new technology before implementing it on board. With the help of instructors (IMO Model Course 6.09, 2001; IMO Model Course 2.07, 2002), it is possible to simulate conditions five or ten years ahead and measure the effectiveness of a fully implemented system, before committing the industry to a particular path. This is particularly important when training young people to meet future challenges. Training is costly and is made much easier and cheaper if systems have common human-machine interfaces and besides the main advantage of such simulations is that operational scenarios can be tested and evaluated without the need or use of actual experimentation. Today many maritime trainings centres apply engine room simulators in their didactic process.

Benefits of student by the incorporation of engine room simulator into a well focused marine training course are the next: technical knowledge by associating with his peers and absorbing the technical matter presented, the motivation of knowing that students – colleagues are interested in the same subject matter, the personal satisfaction of realizing that his knowledge are on par with those of others, personal acquaintances with serious minded instructors, state of the art solutions to problems where such solutions are not yet published and inspiration to enrol in and attend special courses accumulating continuing education units. Human hazards become less probable with adequate hands-on training, education, proper manning levels and timely and appropriate change management.

Simulator exercises (Kluj, 1999; Gourgoulis et al., 2004; Gourgoulis et al., 2008) could be used as far as practically reasonable to quantify work load, fatigue, stress levels and available time for watch out, decision and planning under conditions of continuously troubleshooting. Also, it must be noted that STCW 95 Convention (S.T.C.W., 1995) strongly recommends the application of engine room simulators in the teaching process. The application of simulators in the professional training of marine engineering is a mandatory requirement as determined by the standards of training, certification and watch keeping, which is an international convention for seafarers. The main objective of convention is to set a minimum level of specialized knowledge and qualification between seafarers.

The careful use of steam turbo generator, the avoidance of water strike in combination with the periodical maintenance, using suitable checklists, can lead to decreased consumption in cases that the demand of power are not extremely high. For this purpose the influence of vital subsystems such as such as rpm governor, throttle steam valve, lubrication oil and steam system with condenser on the normal operation of steam turbo electro generators have been studied.

An attempt to examine the basic malfunctions of steam driven turbo electro generators and especially how they are could be avoided has been made. This paper discusses some of the faults of such systems and provides an insight into the various technical issues associated with the application and maintenance of electrical power systems for marine applications.

These experiments form part of a larger work (Gourgoulis et al., 2004; Gourgoulis et al., 2008) concerning the use of engine simulator that simulates a dynamic real time computerized slow speed main propulsion turbocharged diesel engine incorporating a waste heat steam boiler, a turbo generator and one shaft generator.

LIST OF SYMBOLS

TG	Turbo Generator
ALxx	Alarm xx
Mxx	Malfunction xx
LO	Lubrication oil

DESCRIPTION OF SIMULATOR

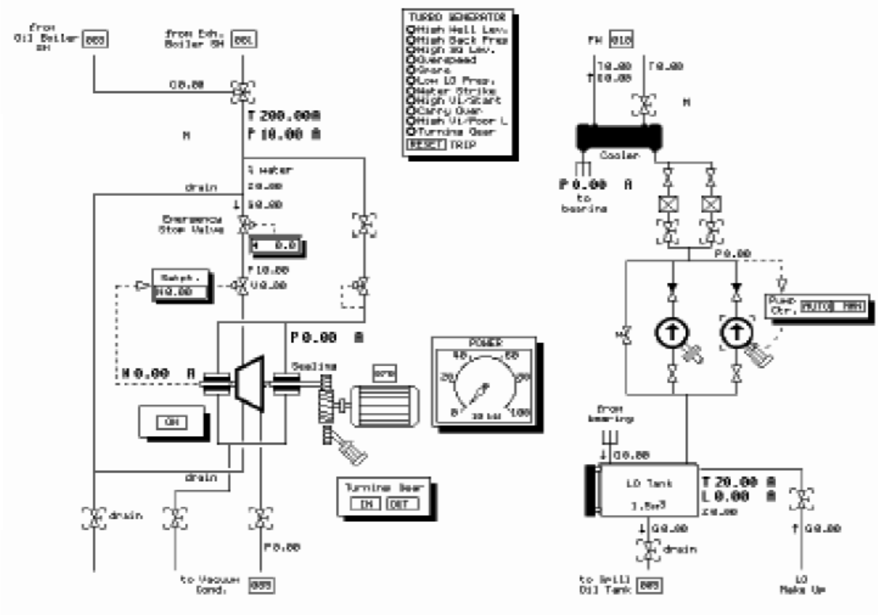
The engine room simulator plant at Merchant Marine Academy of Makedonia was established in 2002 and was designed, implemented and integrated by Kongsberg Nor control Simulation (Kongsberg Nor control, PPT2000-MC90-III, 1999).

The simulator could be divided into two main parts: The simulated Engine Room and the Instructor system. The simulated engine room is arranged as subsystems identical to those found onboard a real Very Large Crude Oil Carrier Ship. The simulation models have been configured by Operator Training Industrial Simulation System software that it has been developed by Special Analysis and Simulation Technology Ltd, England.

Simulator training or research projects of Merchant Marine Academy of Makedonia are realized by the following phases: proposal phase, data collection and implementation, simulation and data recording, analysis and reporting. The instructor system of engine room simulator comprises the facilities and features needed for the instructor to prepare, control and evaluate the simulator training courses or research studies.

The simulated main engine is a B&W 5L90 MC, five cylinder in-line, low speed, two stroke engine with turbo-charging and scavenging air cooling. Turbo generator '*TG*' is an auxiliary generator and with diesel generators in auto operation as stand by generators. *TG* is modelled as high speed turbine with all vital subsystems such as rpm governor, lubrication oil and steam system with condenser [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)]. The turbine is modelled with torque dependent on steam flow, inlet steam pressure/temperature and condenser vacuum. *TG* is fed with superheated steam from the exhaust boiler. The exhaust fire boiler produces steam of approximately 290°C.

The electrical consumption is monitored and compared to the present possible power production. When deviation from present limits arises, the system will act in order to normalize the situation. The system also performs continuous controls of the frequency and load sharing. The preferred mode of operation is with Shaft generator as base generator, *TG* as an auxiliary generator and with two diesel generators in auto as stand by generators. Whenever, possible the *TG* should be prepared and connected and put to auto mode. In this case, the *TG* control must be changed from maximum load to frequency control mode. In auto mode it will be loaded according to available steam pressure. The recommended priority setting is priority 1 for the shaft generator, priority 2/3 for diesel generator 1 and 2. If only the shaft generator and turbo generator are connected there is no difference between operations in equal or optimal mode.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual.

Figure 1: Steam engine driven TG.

In any case, *TG* will take as much power as possible. The *TG* throttle valve is limited to a value sufficient for keeping it connected at minimum steam pressure and close to zero power. The steam pressure must be higher than 9 bar and the steam throttle valve more than 15% lower than limiting value. *TG* can never become slave generator. This is taken care of by the power chief. *TG* has its own logic which means the turbo generator does not take any notice of the different load limits in the different load sharing modes. This is because of the fact that the most economical way to run *TG* is running at full load all the time. Before start of turbo generator vacuum must be established and the condenser must be drained.

Table 1 displays the alarms of steam *TG* (Kongsberg Nor control, PPT2000-MC90-III, 1999). Alarms of *TG* are divided into two types: high and low level alarms. *AL01 – AL07*, rotor displacement (drain water strike or carry over water strike) and *AL10* give a trip signal for the safety protection of turbo generator.

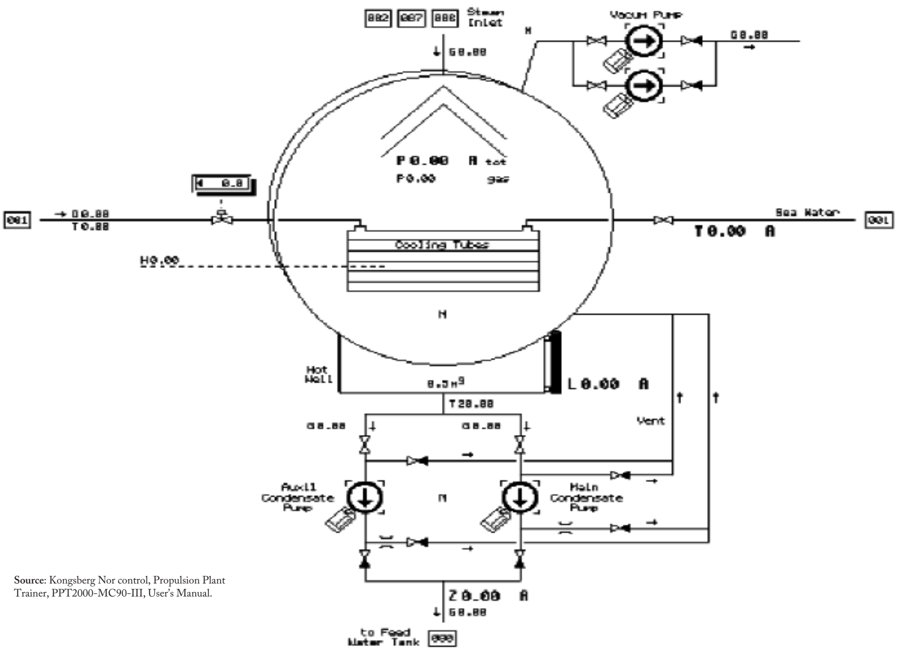
Table 1: Alarms (high-low level) of TG.

HIGH	*AL01*	Condenser hot well water level
	AL02	Condenser pressure (low vacuum)
	AL03	Steam generator water level
	AL04	*TG* over speed
	AL05	Stator temperature
	AL06	Vibration (cold start)
	AL07	Vibration (poor lubrication)
	AL08	*LO* tank temperature
	AL09	Lubrication oil tank level
LOW	*AL10*	*LO* pressure inlet bearings
	AL11	Steam inlet temperature *TG*
	AL12	Steam inlet pressure *TG*
	AL13	Sealing steam pressure

OBSERVATION PLAN

In the examined scenario the ship was running in open sea following the mode '*Full Ahead – Loaded*'. The ambient sea water temperature was 15°*C*, the ambient air temperature was 20°*C* and the ambient air humidity was 50%. Sea water depth was 200 *m*, main engine fuel link position was 94.4% and the main engine speed command was 74 *rpm*. The pitch was fixed and for the electrical power supply shaft and *TG* were in operation.

The turbine (Kongsberg Nor control, PPT2000-MC90-III, 1999) is modelled realistically with torque dependent on steam flow, inlet steam pressure - temperature and condenser vacuum. The throttle valve is controlled by a speed governor. The speed can be remotely adjusted by lower / raise signals from the electric switchboard. Governor of *TG* was a proportional – intergraded (PI) controller with compressed lever (P) and compensating valve (I) to be adjusted to 14.0 (P) and 0.9 sec (I) respectively. The set point of speed was 6464 rpm and the speed drop of turbo generator



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual.

Figure 2: Steam condenser.

was 50%. Before start of *TG* vacuum has been established and the condenser has been drained using the vacuum pump and main condensate respectively [Fig. 2, (Kongsberg Nor control, PPT2000-MC90-III, 1999)]. The required lubrication and freshwater systems for the cooling of *TG* have been prepared [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)].

Several faults have been introduced in order to demonstrate cascading of abnormal conditions that influence the operation of steam *TG*. From Table 2 it can be observed that *M01-M08* malfunctions are related with the operation and subsystems of *TG* (Fig. 1) and the rest *M10-M20* are related with the correct per formation of steam condenser (Fig. 2). Examining the possible malfunctions of *TG* and steam condenser it can be deduced that *M08* (*LO* filter 2, Fig. 1) and *M12-M13* (Auxiliary condensate pump, Fig. 2) were not possible to be activated due to the fact *LO* filter 1 and main condensate pump respectively were in operation. In addition, the next malfunctions (*M07*, *M11*, *M13*, *M15* and *M19*) have not the possibility to be ramped and the starting malfunction point is 100%. The other malfunctions of Table 2 might be ramped from the initial set point 100% to the specified malfunction set point. Faults could be edited on line and for each inserted malfunction the observation time was specified to be 20 minutes in order to have a stable factor for evaluation. Each malfunction (Kongsberg Nor control, PPT2000-MC90-III, 1999) is activated (100%) immediately with the running of scenario.

Table 2: Malfunctions of TG – Steam Condenser.

TG	*AL01*	Condenser hot well water level
	M01	*TG* speed controller gain high
	M02	Turbine efficiency low
	M03	*TG* mechanical *LO* pump wear
	M04	*TG LO* cooler dirty
	M05	*TG LO* filter 1 dirty
	M06	*TG LO* system water inlet leakage
	M07	*TG* gland steam controller fail
	M08	*TG LO* filter 2 dirty
LOWSTEAM CONDENSER	*M10*	Main condensate pump wear
	M11	Main condensate pump motor failure
	M12	Auxiliary condensate pump wear
	M13	Auxiliary condensate pump motor failure
	M14	Vacuum pump 1 wear
	M15	Vacuum pump 1 motor failure
	M16	Vacuum pump 2 wear
	M17	Vacuum pump 2 motor failure
	M18	Vacuum condenser air leakage
	M19	Vacuum condenser dirty
	M20	Vacuum condenser sea water leakage

Activating *M01*, *M02*, *M04*, *M06*, *M08* the behaviour of systems was always the same in the observation period of 20 minutes. In 11:37 minutes from the activation of particular malfunctions one alarm was only presented (Fig. 3). As can be seen from figure 3 the caused alarm 'High aft bilge well level > 0.5m' is not vital for the correct operation of *TG*, there is plenty of time for the re-establishment of damage and for the above reasons malfunctions of Fig. 3 were not reprogrammed at lower percentage of damage.

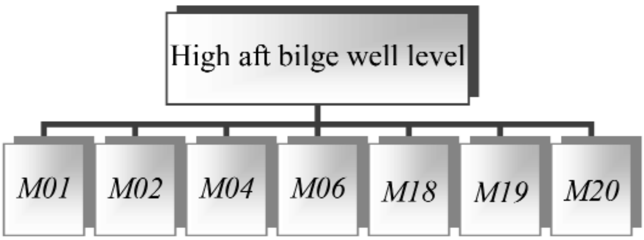
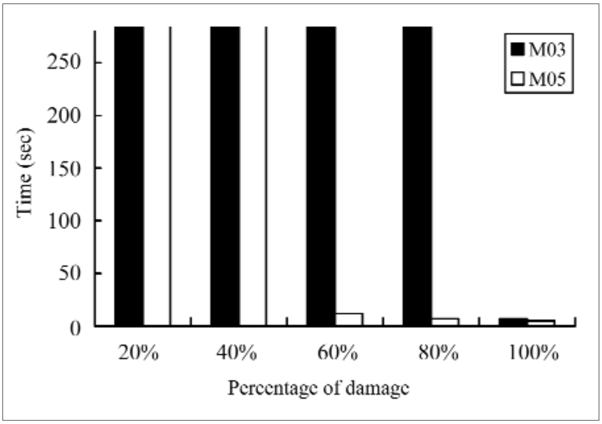


Figure 3: Alarm of malfunctions.

For the demonstration of the *TG* driven alarm *AL10* '*LO* pressure inlet bearings', *M03* '*TG* mechanical *LO* pump wear' was activated after the running of scenario. The lowest limit of pressure for the correct lubrication of inlet bearings is 1,5 *bar*. Figure 4 shows the appearance time of alarm *AL10* at the different stages of produced fault. From this figure it can be seen that the increase of damage over 80% does not give to personnel the adequate time for the quick re-establishment of damage. For the repair of damage [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] was activated the electrical *LO* pump and was deactivated the mechanical *LO* pump. Besides, *AL10* can be presented by the activation of *M05* '*TG LO* filter 1 dirty'. From figure 4 it can be seen that the increase of damage over 40% leads in the activation of *AL10* in 12 *sec* for the avoidance of damage [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] the engineer who is doing watch keeping must inspect periodically the cleanness of *TG LO* filters. The cleanness of *TG LO* filters is not only vital for the operation of *TG* but for the total operation of ship. It was observed that for damages of *M05* over 80% the shutdown of main engine was presented in 6 minutes after the running of scenario.

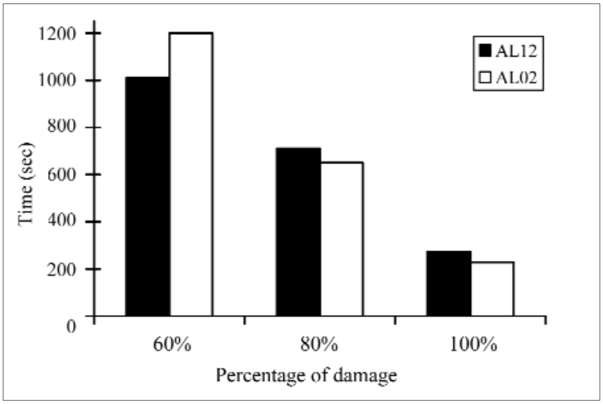
Figure 4: Appearance time of AL10.



■ *M03, TG* mechanical *LO* pump wear
□ *M05, TG LO* filter 1 dirty

For the demonstration of the *TG* driven alarm *AL01* 'Condenser hot well water level', *M10* 'Main condensate pump wear' was activated after the running of scenario. The highest limit of condenser hot well water level is 650 *mm*. It can be observed that the decrease of damage under 80% does not display *AL01*. The careful maintenance of main or auxiliary condensate pump can lead in the avoidance of difficult situations. Besides, for the demonstration of the *TG* driven alarm *AL13* 'Sealing steam pressure' [6], *M07* '*TG* gland steam controller fail' was activated after the running of scenario. *M07* has not the possibility to be ramped and the percentage of damage is 100%.The lowest limit of sealing steam pressure is 0,1 *bar*. It was observed that *AL13* was present in 6 sec after the running of scenario. For the avoidance of damage [Fig. 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] the engineer who is doing watch keeping must inspect periodically the correct adjustment of *TG* gland steam controller.

Figure 5: Average appearance time of AL12 and AL02.



■ *AL12,* Steam inlet pressure *TG*
□ *AL02,* Condenser pressure (low vacuum)

For the demonstration of the *TG* driven alarm *AL12* 'Steam inlet pressure *TG*' a different combination of malfunctions could be used. Six malfunctions (*M03*, *M05*, *M07*, *M10* and *M16*) were able to cause *AL12*. In the same way, for the demonstration of the *TG* driven alarm *AL02* 'Condenser pressure (low vacuum)' three malfunctions (*M16* and *M17*) could be programmed. The lowest limit of steam inlet pressure to *TG* is 7,0 *bar* and the highest limit of condenser pressure is 0,2 *bar*. Figure 5 shows the average appearance time of alarm *AL12* and *AL02* at the different stages of produced faults. From this figure it can be seen that the increase of damage over 80% does not give to personnel the adequate time for the quick re-establishment of damage. Finally it can be observed that for damages of *M16* over 60% the shutdown of main engine was presented in 4 minutes after the running of scenario.

CONCLUSIONS

Human factors are related to crew competence in terms of decision-making, communication, operating skills. Human error is an existence parameter that often proves almost impossible to remove from the maritime safety formula. Thus, the human failures can be avoided by different ways: firstly by improving the management and crew organisation; then by doing a careful selection of the crew and thirdly by increasing the training quality and quantity, both for ordinary and emergency situations. The use of marine simulators would improve both the training and the selection.

In open sea, *TG* is mainly an auxiliary generator and for the avoidance of malfunctions that influence the normal operation of *TG* during the drip, daily, officer in charge of an engineering watch keeping (IMO Model course 7.04, 1999; IMO Model course 7.02, 1999) must check the cleanness of *TG LO* filters, the correct function of lubricant mechanical or electrical oil pump, the effective operation of auxiliary or main condensate pump, the correct adjustment of *TG* gland steam controller and the total function of steam condenser. Examining all produced faults it was deduced that the most dangerous faults were *M05* '*TG LO* filter 1 dirty' and

M16 'Vacuum pump 2 wear'. It was observed that for damages of *M05* and *M16* over 80% and 60% respectively the shutdown of main engine was presented in very short period after the running of scenario.

In order to avoid trip signal of *TG* breaker due to water strike, rotor displacement and vibration is recommended *TG* to start without the presence of water in the line of steam, the increase of speed of *TG* to become very slow, the emergency stop valve to open very late keeping the speed of *TG* at low limits in case of cold *TG*. The *TG* is protected by a separate safety system and trip signal is given on the following conditions: low *LO* pressure (by the activation of *M05*) high back pressure (by the activation of *M14*, *M16* and *M17*).

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IMO (1999): International Maritime Organization, Model course 7.04, Officer in charge of an engineering watch.

IMO (1999): International Maritime Organization, Model course 7.02, Chief engineer officer and second engineer officer.

LOCALIZACIÓN DE AVERÍAS EN LOS ELECTRO TURBO DE VAPOR DE LOS GENERADORES MARINOS USANDO EL SIMULADOR DE LA SALA DE MÁQUINAS

Resumen

La puntería del actual estudio es examinar la operación diaria del vapor - generadores accionados por el motor de turbo electro usados en la ingeniería marítima para el sistema de fuente auxiliar de la corriente eléctrica de nave en la operación en tiempo real y bajo malfuncionamientos. En la nave, el modo de operación preferido está con el generador de eje como generador bajo, el generador de turbo como generador auxiliar y con los generadores diesel en la operación auto como hace una pausa los generadores. Generador de Turbo modelado como turbina de alta velocidad con todos los subsistemas vitales tales como gobernador de la rpm, aceite de lubricación y sistema del vapor con el condensador. El estudio de la investigación intenta hacer análisis de la falta y además de para proporcionar las soluciones para los problemas verdaderos del funcionamiento. El uso del simulador bajo condiciones anormales ayuda al instructor y a los estudiantes a entender mejor el proceso mientras que al mismo tiempo contribuye perceptiblemente al desarrollo del alcohol de equipo y refuerza respecto y la cooperación mutuos entre a muchas funciones de trabajo en la planta.

INTRODUCCIÓN

La organización marítima internacional (S.T.C.W., 1995) tiene un papel dominante a jugar en la puesta en práctica acertada de la nueva tecnología en el mar. En línea, con políticas actuales en la gestión de riesgos y factores humanos, será recomendable investigar los efectos de largo plazo completos de la introducción de cada nuevo ambiente de trabajo del sistema en general, considerando parámetros tales como el diseño de sistema, mantenimiento, confiabilidad y el entrenamiento. Además, a bordo tecnología debe ser amistoso, debe dejar a seres humanos en control y no debe aislar al usuario del ambiente exterior.

Uno de los propósitos principales de la simulación de computadora es imitar las operaciones de los sistemas o de los procesos de la vida real. El advenimiento de los simuladores del sitio del puente y de motor y de su uso como herramientas modernas de la investigación, ahora, permite que probemos nueva tecnología antes de ejecutar de ella a bordo. Con la ayuda de los instructores (IMO Model Course 6.09, 2001; IMO Model Course 2.07, 2002), es posible simular condiciones cinco o diez años a continuación y medir la eficacia de un sistema completamente ejecutado, antes de confiar la industria a una trayectoria particular. Esto es particularmente importante al entrenar a gente joven hacer frente a desafíos del futuro. El entrenamiento es costoso y se hace mucho más fácil y más barato si los sistemas tienen interfaces persona-máquina comunes y además de la ventaja principal de tales simulaciones es que los panoramas operacionales se pueden probar y evaluar sin la necesidad o el uso de la experimentación real. Muchos centros de entrenamientos marítimos aplican hoy los simuladores del sitio de motor en su proceso didáctico.

Las ventajas del estudiante por la incorporación del simulador del sitio de motor en un curso de aprendizaje marina enfocado pozo son las siguientes: el conocimiento técnico asociándose a sus pares y absorbiendo la materia técnica presentó, la motivación de saber que los estudiantes - los colegas están interesados en el mismo tema, la satisfacción personal de realizar que su conocimiento está junto con los de otros, conocidos personales con los instructores importados serios, soluciones avanzadas a los problemas donde tales soluciones todavía no se publican e inspiración para alistar adentro y para atender a los cursos especiales que acumulan unidades de la formación permanente. Los peligros humanos llegan a ser menos probables con el entrenamiento con manos adecuado, la educación, los personal apropiados y la gerencia oportuna y apropiada del cambio.

Los ejercicios del simulador (Kluj, 1999; Gourgoulis et al., 2004; Gourgoulis et al., 2008) se podrían utilizar hasta prácticamente razonable para cuantificar la cantidad de trabajo, la fatiga, niveles de tensión y la hora disponible para tienen cuidado, decisión y planeamiento bajo condiciones continuamente de la localización de averías. También, debe ser observado que la convención de la STCW 95 (S.T.C.W., 1995) recomienda fuertemente el uso de los simuladores del sitio de motor en el proceso de enseñanza. El uso de simuladores en el entrenamiento profesional de la arquitectura naval es un requisito obligatorio según lo determinado por los estándares del entrenamiento, de la certificación y del reloj guardando, que es una convención internacional para los navegantes. El objetivo principal de la convención es fijar un nivel mínimo de conocimiento y de calificación especializados entre los navegantes.

El uso cuidadoso del generador de turbo del vapor, la evitación de la huelga del agua conjuntamente con el mantenimiento periódico, usando listas de comprobación convenientes, puede llevar a la consumición disminuida en casos que la demanda de la energía no es extremadamente alta. Con este fin la influencia de subsistemas vitales tales como por ejemplo el gobernador de la rpm, la válvula de vapor de la válvula reguladora, el aceite de lubricación y el sistema del vapor con el condensador en la operación normal generadores de turbo del vapor de los electro se ha estudiado.

Se ha hecho una tentativa de examinar los malfuncionamientos básicos de los electro generadores conducidos vapor de turbo y especialmente cómo son se podría evitar. Este papel discute algunas de las averías de tales sistemas y proporciona una penetración en las varias ediciones técnicas asociadas al uso y al mantenimiento de los sistemas eléctricos eléctricos para los usos marinas.

Estos experimentos forman la parte de un trabajo más grande (Gourgoulis et al., 2004; Gourgoulis et al., 2008) referente al uso del simulador del motor que simula un motor diesel turbocharged automatizado tiempo real dinámico de la propulsión principal despacio que incorpora una caldera de vapor del calor residual, un generador de turbo y un generador de eje.

CONCLUSIONES

Los factores humanos se relacionan con la capacidad del equipo en términos de toma de decisión, comunicación, funcionando habilidades. El error humano es un parámetro de la existencia que prueba a menudo casi imposible quitar de la fórmula de la seguridad marítima. Así, las faltas humanas se pueden evitar por las maneras diferentes: en primer lugar mejorando la organización de la gerencia y del equipo; entonces haciendo una selección cuidadosa del equipo y en tercer lugar aumentando la calidad y la cantidad del entrenamiento, para el ordinario y las situaciones de emergencia. El uso de simuladores marinas mejoraría el entrenamiento y la selección.

En el mar abierto, el *TG* es principalmente un generador auxiliar y para la evitación de los malfuncionamientos que influencian la operación normal de *TG* durante el goteo, diario, oficial a cargo de un reloj de ingeniería que guarda (IMO Model course 7.04, 1999; IMO Model course 7.02, 1999) deben comprobar la limpieza de los filtros del TG LO, la función correcta de la bomba mecánica o eléctrica del lubricante de aceite, la operación eficaz de la bomba condensada auxiliar o principal, el ajuste correcto del regulador del vapor de la glándula del *TG* y la función total del condensador del vapor.

Para evitar la señal del viaje del triturador del *TG* debida regar huelga, la dislocación del rotor y la vibración es *TG* recomendado a comenzar sin la presencia de agua en la línea de vapor, el aumento de la velocidad del *TG* a llegar a ser muy lento, la válvula de parada de emergencia para abrir muy tarde la custodia de la velocidad del *TG* en los límites bajos en caso del *TG* frío. El *TG* es protegido por un sistema de seguridad separado y la señal del viaje se da en las condiciones siguientes: presión trasera baja de la presión de *LO* (por la activación de *M05*) alta (por la activación de *M14*, de *M16* y de *M17*).

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CORROSION WASTAGE MODELING FOR DIFFERENT MEMBER LOCATIONS OF AGED BULK CARRIERS

Bauk, S.[1]; Nikolic, D.[1]; Ivosevic. S.[1]

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ABSTRACT

The paper considers two corrosion wastage models for some pre-specified member locations of several aged bulk carriers. Accordingly, the available statistical data of regular corrosion measurements for existing bulk carriers' structures have been analyzed, using two simulation models. The first considered model is based on Monte Carlo simulation method and it is developed upon cumulative data collected by measuring eleven structure categories of ten bulk carriers during the period between the twentieth and the thirtieth year of their operational life. The second considered model employs an inverse analysis of the corrosion process in the case of seven bulk carriers' inner bottoms plating areas at different ages of the ships' operational life, i.e. their exposure to the corrosion. Both models show certain convergence and enable predicting the steel amounts that are to be removed (replaced) from different corroded structural members in order to keep the ultimate bulk carriers' both transversal and longitudinal strength within the boundaries of required safety level.

Key words: aged bulk carriers, corrosion wastage, ships' structure strength control.

INTRODUCTION

In ageing process of bulk carriers, corrosion and fatigue cracks are two most important factors affecting structural safety and integrity. There are several types of corrosion. The most common ones are: general (uniform) corrosion, which uniformly

[1]Assistant professor, Faculty of Maritime Studies, University of Montenegro, email: bsanjaster@gmail.com, Tel: 38232303184, Fax: 38232303184, Dobrota 36, 85330 Kotor, Montenegro.

reduces the member wall thickness, and localized (pitting or grooving) corrosion, that causes degradation in local regions. The corrosion, in general, is influenced by many factors including the corrosion protection system and various operational parameters. Most often, the corrosion protection systems for vessels are coatings and anodes. Among the operational parameters, the following might be included: maintenance, repair, type of cargo, kind of loading/unloading operations, i.e. manipulation techniques and equipment, percentage of time in ballast, frequency of tank cleaning, temperature profiles, use of heating coils, humidity conditions, water and sludge accumulation, microbial contamination, atmosphere effects, composition of fuels and inert gases, etc. Also, the various uncertainties associated with corrosion are to be taken into consideration, where a probabilistic treatment is essential. Now-a-days, the lack of understanding of all these factors and their mutual interactions is present, although related experiences for each of them looking solely have been documented and sometimes analyzed (Adey and Baynham, 2000; Guo et al, 2008; Paik et al 1998; Paik et al, 2003; Paik and Thayamballi, 2002; Qin and Cui, 2002).

Within this paper, two problems related to two groups of ten ageing bulk carriers shall be considered as well as their general (uniform) corrosion processes: (1) - predicting the appropriate value of the steel amount that is to be replaced at a certain member of the structure per year, by Monte Carlo simulations, and (2) - modeling the corrosion depth inverse function due to the past data collected on removed/replaced steel amounts during the various time segments (periods) of the observed bulk carriers operational life.

MONTE CARLO SIMULATION AND PREDICTIVE CORROSION WASTAGE MODEL FOR BULK CARRIERS STRUCTURES

Generally speaking, the concept of simulation involves developing a mathematical model that attempts to describe a real-world situation. The model's goal is to incorporate important variables and their interrelationships in such way that we can study the impact of different decisions on functioning of the whole system. This approach has many advantages over other decision modeling techniques and it is especially useful, when a problem is too complex or difficult to solve by other means. The Monte Carlo method of simulation uses random numbers to generate random variable values from probability distributions. The simulation procedure is conducted for several time periods to evaluate the long-term impact of each policy value being studied (Shogan, 1998).

Generating random numbers and setting up the simulation

The function of computer generation of random numbers is the generation of decimal fractions (e.g. 0.67185) randomly distributed over the interval from 0 up to, but not including, 1. Hereafter we refer to such random number as a U(0,1) random number. The most common method of generating U(0,1) random numbers is called the *mixed congruential method* (MCM). The MCM generates a sequence of U(0,1) random numbers denoted by r_0, r_1, r_2, r_3,…, and so on. The first number in the sequence, r_0, is an arbitrary chosen decimal fraction between 0 and 1. Using r_0 to initialize the process, the MCM generates the next random number using the previous random number and the following formula:

$$r_i = \frac{[(m \cdot a \cdot r_{i-1} + c)(modulo(m))]}{m} \qquad (1)$$

were

m – is prespecified positive integer known as modulus;

a – is prespecified positive integer less than m known as the multiplier;

c – is prespecified nonnegative integer less than m known as the increment.

Strictly speaking, the sequence of numbers generated by MCM is not random in the sense of being unpredictable and irreproducible. It is obvious, by specifying *m*, *a* and *c*, it is automatically determined what sequence of numbers shall be generated. For this reason, random numbers generated on a computer are often called pseudo random numbers. A computer needs only to generate U(0,1) random numbers because they in turn can be used to simulate any desired probability distribution.

No.	Bulk carrier structure members/categories	Acronyms
1.	Upper deck	UD
2.	Deck superstructure	DS
3.	Bottom and side shell plating	BSSP
4.	Hatch cover and coamings	HCC
5.	Internal structure in top side tanks	ISTST
6.	Cargo hold transverse bulkheads	CHTB
7.	Cargo hold main frames	CHMF
8.	Inner bottom and hopper plating	IBHP
9.	Internal structure in double bottom tanks	ISDBT
10.	After peak structures	APS
11.	Fore peak structures	FPS

Table 1. The primary members of the bulk carriers being taken into consideration.

The Monte Carlo simulation method has been used in the paper in creating the corrosion wastage predictive model in the sense of which amount of the steel in tons is to be removed/replaced at a certain member location of the considered bulk carriers overall hull structure. Accordingly, first of all, 11 member locations/categories have been specified, including both transversal and longitudinal segments. Some of these member locations/categories consist of only longitudinal members (UD, DS, BSSP, IBHP), or, only transversal members (CHTB, CHMF), while some consist of both longitudinal and transversal members (HCC, ISTST, ISDBT, APS, FPS). It is to be pointed out here that the previous studies in this domain included and treated mostly the longitudinal elements, only. The suggested division of the bulk carrier structure members/categories is given in Table 1.

In aim to get better insight into locations of the members distributed throughout the bulk carrier hull structure (Table 1), 2D bulk carrier's longitudinal view, and 3D cargo hold cross-section, are given in Figure 1.

To predict likely corrosion damage tolerance, or a steel amount to be replaced at a certain area *a priori*, it is necessary to make estimates of the corrosion rates for various structural members grouped by location and some other relevant parameters as it is

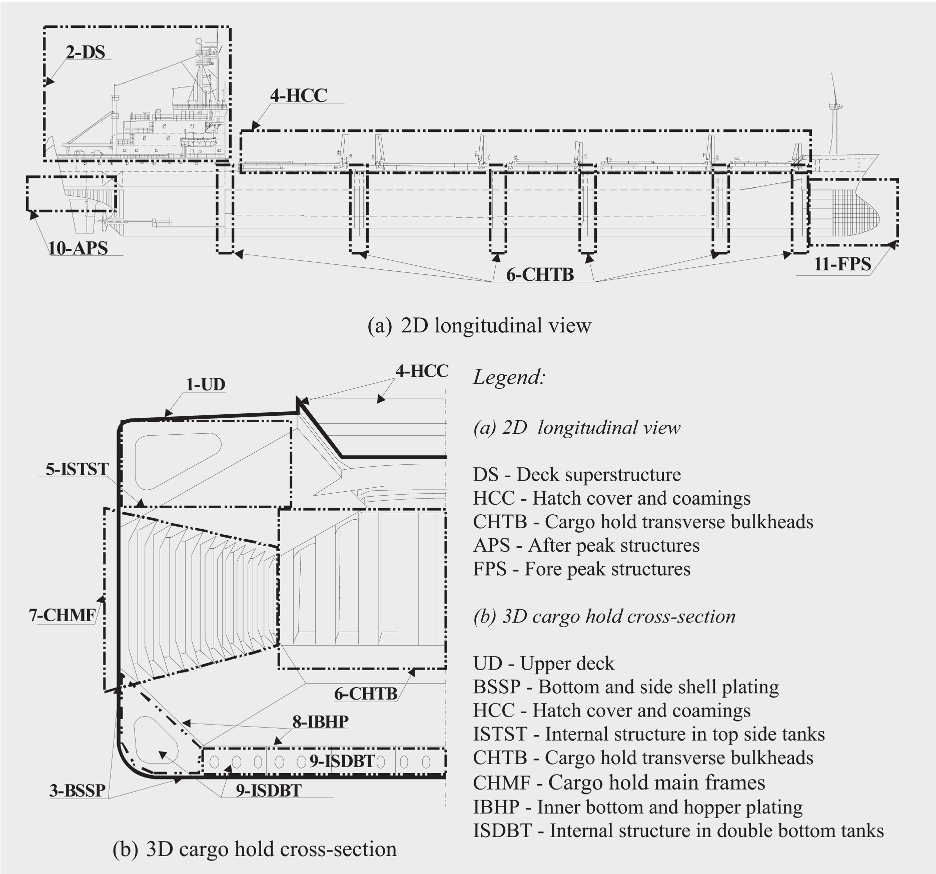


Figure 1. Structural categories identification.

previously done. The appropriate estimations are done in this research at two different levels. The first is the experimental one, realized by Monte Carlo simulation method, and the other one is experience based, i.e. it is based on the expert's knowledge in the domain, being gathered during the years of the working experiences, and later used in making corrections in the results obtained by Monte Carlo method. In other words, Monte Carlo has been used in predicting the amounts of the steel which are to be replaced at each of above identified bulk carriers' structure members per year. Afterwards, the comparison with the expert's knowledge has been performed and the proper corrections have been made in a way described later in the paper.

In aim to realize Monte Carlo simulation the set of homogenous historical data are collected over the previously specified primary transversal and longitudinal bulk carriers' structure members by the recommended standard measurements during the ten years period, that is, during the period between the twentieth and the thirtieth year of the ships operation life. The cumulative data, collected by measuring ten bulk carriers (BC_1-BC_{10}), or more precisely, by measuring more than 300.000 gauged points properly distributed throughout the bulk carriers' hull structures, are given in Table 2.

Table 2. The cumulative data on steel amounts [t] removed/replaced at ten bulk carriers structure members between its 20th and 30th year of operation

No.	Memb.	BC_1	BC_2	BC_3	BC_4	BC_5	BC_6	BC_7	BC_8	BC_9	BC_{10}
1.	UD	1	22	1	30	150	7	165	80	1	12
2.	DS	3	6	1	2	4	6	22	5	0	0
3.	BSSP	3	65	3	45	10	5	60	25	5	3
4.	HCC	7	15	3	15	35	32	40	35	3	25
5.	ISTST	8	9	25	30	45	75	160	120	45	6
6.	CHTB	2	65	25	170	32	45	145	220	24	16
7.	CHMF	3	45	16	85	22	32	85	110	26	25
8.	IBHP	5	550	15	650	440	150	650	85	120	110
9.	ISDBT	20	50	30	35	40	45	55	45	22	2
10.	APS	5	40	25	5	30	14	30	12	9	2
11.	UD	1	6	14	5	20	32	60	55	16	3

As numerous other simulation methods, Monte Carlo method is an experiment in which we attempt to understand how something will behave in reality by imitating its behavior in an artificial environment that approximates reality as closely as possible. Thus, a Monte Carlo simulation creates an artificial environment that approximates reality – here, in this paper, the real corrosion time-dependent process at the group of aged bulk carriers. It conducts computer based experiments over past data that would be too costly and time-consuming to perform in reality. Because Monte Carlo simulation generates random numbers (data), obtaining accurate results requires the simulation to consist of large number of repetitions or runs, or trials. Since it generates random data, there is no guarantee that the chosen policy is actually the optimal one, but the simulation results, undoubtedly, can offer some effective directives for further investigations and comparative analysis due to the expert knowledge.

Results and discussion

The simulation procedure has been realized using Microsoft Excel and it's built-in functions RAND ( ) and LOOKUP (*.*) (Balakrishnan, Render and Stair, 2007) over the data set presented in Table 2. In accordance to the Monte Carlo simulation method, the frequencies of each steel amounts [t] which are replaced at the certain ships' structure members are determined. Then, the probabilities of these amounts appearances in the model are calculated. Later on, the cumulative probabilities and the corresponding random numbers intervals have been set up. The Monte Carlo simulation has been realized throughout two sub-sets of 50.000 runs or trials, i.e. through 100.000 passes in total. Some of the simulation results obtained for the most specific, or, corrosion most sensitive segment of the observed bulk carrierrs' structures – IBHP, are shown in Table 3.

Table 3. Some Monte Carlo simulation results gained for the bulk carriers' IBHP structure members by Excel functions (RN, LOOKUP, COUNTIF)

Steel amounts [t] replaced per year	Frequency	Simulation results				
		RN		LOOKUP		COUNTIF
0.5	1	0.20390	0.04756	8.5	0.5	4981
1.5	1	0.84065	0.78524	65	55	5090
8.5	1	0.94182	0.84977	65	65	5203
11	1	0.97472	0.55561	65	15	4952
12	1	0.08724	0.42820	0.5	12	4944
15	1	0.25933	0.66248	8.5	44	4925
44	1	0.66063	0.97846	44	65	4942
55	1	0.56119	0.30718	15	11	4969
65	2	0.88060	0.68039	65	44	9994
		0.91545	0.61109	65	44	50000
		0.78696	0.08944	55	0.5	
		0.85812	0.30362	65	11	
		0.38058	0.92609	11	65	
		0.32778	0.66141	11	44	
		0.10183	0.44175	1.5	12	
		0.99021	0.15439	65	1.5	
		0.19375	0.93025	1.5	65	
		0.42175	0.79236	12	55	
		0.60576	0.97135	44	65	
		0.80586	0.16350	65	1.5	
		0.94447	0.96588	65	65	
		0.31684	0.17888	11	1.5	
		0.41117	0.26860	12	8.5	
		0.93964	0.00113	65	0.5	
		0.47111	0.25392	12	8.5	
		0.33747	0.99960	11	65	
		...	...	...	...	
			up to 50000 trials		up to 50000 trials	

The simulations presented in Table 3 have been realized through 50000 trials. This number of trials can be multiplied due to the level of simulation model reliability requirements. Similarly, the above presented procedure has been realized for the rest of considered bulk carriers' structure members, and the obtained results are presented in Table 4. Latter on, the obtained results have been confronted with the experts' expectations.

Table 4. The estimated steel amounts [t] that should be replaced at the certain ship structure member per year (shadowed fields), obtained by Monte Carlo simulation method.

Member	Steel amounts[t] / number of random appearances through the simulation process											Total number of runs
UD	Amount $^{Freq.}$	0.1^{3}	0.7^{1}	1.2^{1}	2.2^{1}	3.0^{1}	8.0^{1}	15.0^{1}	16.5^{1}			Σ 100 000
	Appearing no.	29964	9795	10088	10150	10055	9906	10085	9957			
DS	Amount $^{Freq.}$	0.0^{2}	0.1^{1}	0.2^{1}	0.3^{1}	0.4^{1}	0.5^{1}	0.6^{2}	2.2^{1}			Σ 100 000
	Appearing no.	19978	10072	10103	10058	9793	10085	19811	10100			
BSSP	Amount $^{Freq.}$	0.3^{3}	0.5^{2}	1.0^{1}	2.5^{1}	4.5^{1}	6.0^{1}	6.5^{1}				Σ 100 000
	Appearing no.	30068	20048	10029	10027	10026	9809	9993				
HCC	Amount $^{Freq.}$	0.3^{2}	0.7^{1}	1.5^{2}	2.5^{1}	3.2^{1}	3.5^{2}	4.0^{1}				Σ 100 000
	Appearing no.	19958	9977	19962	9944	10088	20074	9997				
ISTST	Amount $^{Freq.}$	0.6^{1}	0.8^{1}	0.9^{1}	2.5^{1}	3.0^{1}	4.5^{2}	7.5^{1}	12.0^{1}	16.0^{1}		Σ 100 000
	Appearing no.	9996	9968	9986	10031	9773	20114	10079	10032	10020		
CHTB	Amount $^{Freq.}$	0.2^{1}	1.6^{1}	2.4^{1}	2.5^{1}	3.2^{1}	4.5^{1}	6.5^{1}	14.5^{1}	17.0^{1}	22.0^{1}	Σ 100 000
	Appearing no.	9872	9992	10146	9968	10130	9923	9988	10045	10046	9890	
CHMF	Amount $^{Freq.}$	0.3^{1}	1.6^{1}	2.2^{1}	2.5^{1}	2.6^{1}	3.2^{1}	4.5^{1}	8.5^{2}	11.0^{1}		Σ 100 000
	Appearing no.	10053	9943	10066	9805	9994	10105	10096	20002	9936		
IBHP	Amount $^{Freq.}$	0.5^{1}	1.5^{1}	8.5^{1}	11.0^{1}	12.0^{1}	15.0^{1}	44.0^{1}	55.0^{1}	65.0^{2}		Σ 100 000
	Appearing no.	10185	9985	9817	9965	9970	10052	9957	10099	19970		
ISDBT	Amount $^{Freq.}$	0.2^{1}	2.0^{1}	2.2^{1}	3.0^{1}	3.5^{1}	4.0^{1}	4.5^{2}	5.0^{1}	5.5^{1}		Σ 100 000
	Appearing no.	9884	10138	9942	10122	9901	9901	9918	20071	9988		
APS	Amount $^{Freq.}$	0.2^{1}	0.5^{2}	0.9^{1}	1.2^{1}	1.4^{1}	2.5^{1}	3.0^{2}	4.0^{1}			Σ 100 000
	Appearing no.	10013	19905	10156	10000	10111	9995	19962	9858			
UD	Amount $^{Freq.}$	0.1^{1}	0.3^{1}	0.5^{1}	0.6^{1}	1.4^{1}	1.6^{1}	2.0^{1}	3.2^{1}	5.5^{1}	6.0^{1}	Σ 100 000
	Appearing no.	10243	10164	9789	10022	10026	10039	9962	10016	9860	9879	

The shadowed steel amounts represent the amounts that randomly appear in the biggest number of simulation trials. Those values should be the optimal ones to be replaced at the certain ship structure member per year, but since the simulation method includes random processes, random variables and their random values, it can not guarante that the obtained simulation results are indeed the optimal ones. Though, they are to be tested in such way to be compared later to the expert knowledge.

Improving the model

Due to the experts' knowledge, internal structure in top side tanks (ISTST), cargo hold transverse bulkheads (CHTB) and inner bottom and hopper plating (IBHP) are the most sensitive and important for the bulk carrier strength, though they should need additional analyzing and simulating in the process of finding optimal solution. Again, according to the experts' experiences the average value of the steel amounts which have to be replaced per year at certain member/category of the ship's structure might be the right orienteer in achieving improvements in the simulation model. In other words, the simulation model should be satisfying *reliable* if it gives *optimal* values that are close to the average values of the steel amounts [t] to be removed/replaced at above pointed member structure areas. The schematic representations of the experts' suggestions in the direction of Monte Carlo simulation model improving and the way of attempting to achieve them, is presented in Figure 2.

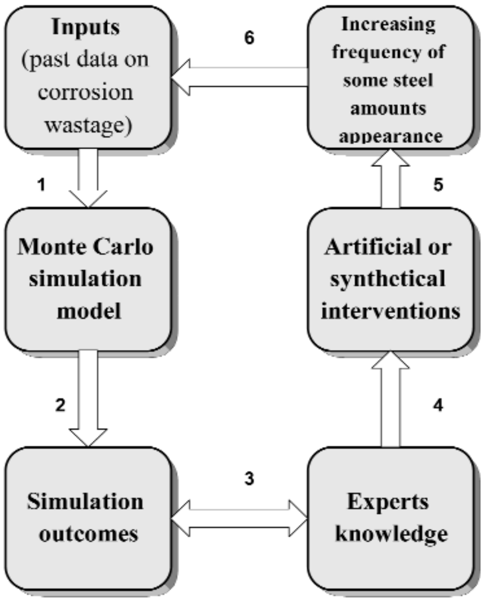


Figure 2. The scheme of possible improvements of the Monte Carlo simulation modeling.

Afterwards, the question is drawn: how to achieve the suggested *improvements* of the proposed and here applied Monte Carlo simulation model? - The simplest and the most effective way is to *artificially* adjust some values in the model (i.e. for ISTST, CHTB and IBHP) to be close, or closer, to the average values of steel amounts that are to be removed/replaced at each considered area. This could be done by adding / subtracting *artificially* appropriate small amounts of steel to the listed ones (see tables 3 and 4) in aim to increase frequencies of appearing the values close to the average one for the certain ship's structure member in the model. In such way, the possibilities for the *right* values appearance as the optimal ones at the end of numerous runs of the Monte Carlo simulation process shall be undoubtedly higher.

The frequency of a certain value appearance in the model initial (input) matrix of data is of the crucial importance for obtaining *wanted* or valid (final) results for the considered problem. Thus, the main qualitative contribution of these experiments might be: the frequency of a certain value appearing in the model input matrix is the crucial in obtaining the optimal solution after series of simulation runs. Additionally, due to the experts' knowledge in this domain, the best way to make simulation results closer to the real situation it is to adapt the initial model in a way to increase *artificially* frequencies of appearing the values close to the average one (by adding/subtracting enough small values for steel amounts). By such interventions model can be generally used in predicting the optimal amounts of the steel to be removed/replaced at each bulk carrier's structure area on the bases of the past collected data and their slight corrections due to experts' knowledge in the field.

The achieved improvements in the case of the considered problem are presented in the Table 5. It is obvious that the optimal results obtained by Monte Carlo simulation are considerably closer to the average amounts for ISTST, CHTB and IBHP bulk carrier's structure members, than in the first sequence of experiments (Table 4).

Table 5. The improved results of Monte Carlo simulation achieved owing to the experts' knowledge in the domain

Member	Steel amounts[t] / number of random appearances through the simulation process											Total number of runs
ISTST	Amount Freq.	0.6^{1}	0.8^{1}	0.9^{1}	2.5^{1}	3.0^{1}	4.5^{2}	7.5^{1}	12.0^{1}	16.0^{1}		0.52 (avg)
	Appearing no.	9996	9968	9986	10031	9773	20114	10079	10032	10020		Σ 100 000
ISTST(1)	Amount Freq.	0.5^{3}			2.5^{1}	3.0^{1}	4.5^{2}	7.5^{1}	12.0^{1}	16.0^{1}		
	Appearing no.	30284			10164	9882	19822	9796	10057	9995		Σ 100 000
CHTB	Amount Freq.	0.2^{1}	1.6^{1}	2.4^{1}	2.5^{1}	3.2^{1}	4.5^{1}	6.5^{1}	14.5^{1}	17.0^{1}	22.0^{1}	0.74 (avg)
	Appearing no.	9872	9992	10146	9968	10130	9923	9988	10045	10046	9890	Σ 100 000
CHTB(1)	Amount Freq.	0.7^{3}			2.5^{1}	3.2^{1}	4.5^{1}	6.5^{1}	14.5^{1}	17.0^{1}	22.0^{1}	
	Appearing no.	30108			9946	9963	10135	9961	9882	9930	10075	Σ 100 000
IBHP	Amount Freq.	0.5^{1}	1.5^{1}	8.5^{1}	11.0^{1}	12.0^{1}	15.0^{1}	44.0^{1}	55.0^{1}	65.0^{2}		2.78 (avg)
	Appearing no.	10185	9985	9817	9965	9970	10052	9957	10099	19970		Σ 100 000
IBHP(1)	Amount Freq.	3.0^{3}			11.0^{1}	12.0^{1}	15.0^{1}	44.0^{1}	55.0^{1}	65.0^{2}		
	Appearing no.	30039			10125	9869	9965	9926	10190	19886		Σ 100 000

The proposed way of improving *reliability* of Monte Carlo should be tested at greater amount of data, collected for example by different companies and/or ships' classification societies. Afterwards, the whole process should be *automated* by developing the appropriate software application for easier and quicker model realization.

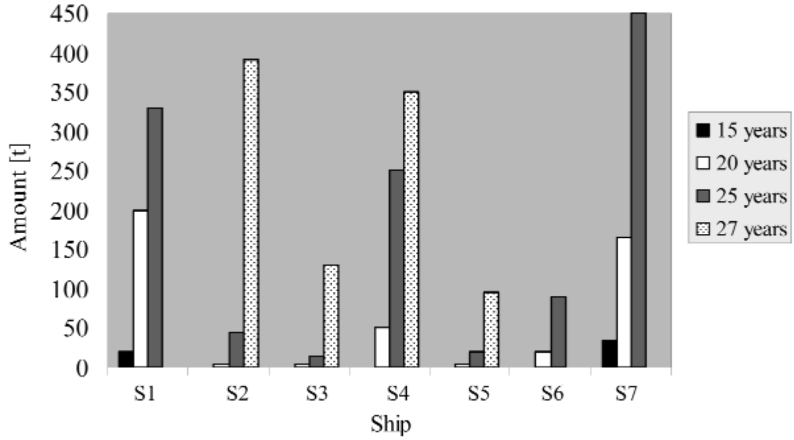
Within the next section, the second corresponding corrosion predictive model based upon rather uncommon inverse analysis of the time-dependent bulk carriers' corrosion wastage.

Some analysis of time-dependent corrosion wastage model

Up to now, several time-dependent corrosion wastage models have been developed upon the appropriate homogenous historical (statistical) data (Wang et al, 2008). Most of these models consider depth of steel degradation (d [mm/year]) at a certain ship's area. Here, within this paper an effort has been done to represent corrosion degradation through the amounts of steel which have been replaced at the certain bulk carrier's areas due to the severe corrosion wastage of the structure material.

Accordingly, the data collected by regular thickness measurements at the group of seven bulk carriers have been used. Since the inner bottom plating (IBHP) areas are in the greatest measure exposed to the corrosion, only these structure members were examined here. The Figure 3 shows the histogram of corrosion wastage (replaced amounts of steel [t]) of inner bottom plating at selected ship's ages (15, 20, 25, 27) over the examined set of seven bulk carriers.

Figure 3. The histogram of corrosion wastage of inner bottom plating at selected ship's ages at an exemplar of seven bulk carriers.



The durability of coating, transition between coating durability and corrosion initiation, and the process of corrosion, might be represented with a time-dependent functional equation of the following type [3] (Soares and Garbatov, 1999):

$$d(t) = d_{\infty}\left(1 - e^{-\frac{t-\tau_c}{\tau_t}}\right) \tag{2}$$

were

d(t) is the corrosion wastage at time t;
d∞ is the long-corrosion wastage;
τ_c is the time without corrosion to the start of failure of the corrosion protecting coating;
τ_t is the transition time duration.

Since corrosion data has a very large variability, the time-dependent functional equation (2) should not be taken into the consideration as "the only" or as "the best" one. It has been used here as an equation that satisfies the requirements of an approximation of corrosion wastage considered in the paper. Namely, it is well known, that most corrosion data are relatively largely scattered. What can be treated as novel here, due to the authors' experience is an attempt to realize some *inverse* analysis of the equation (2) in manner to find an approximate function which corresponds to the amounts of steel replaced during the ship exploitation circle. Mostly, previous works in this domain were oriented toward the depths of steel damages caused by the corrosion processes (Soares and Garbatov, 1999). However, here is presented an attempt to determine approximately functional equation that corresponds to the removed (replaced) steel amounts over certain ship structure area. After some analytical analysis and numerous simulation trials (in Matlab) it has been realized that function of type (3) might be used, with satisfying accuracy, in modeling the steel amounts to be replaced at bulk carriers' inner bottom plating areas during the time:

$$Q(t) = e^{\frac{t-\tau_c}{\tau_t}} - 1 \tag{3}$$

were

Q (t) is the steel amount replaced/removed over certain ship's area;
τ_c is the time without corrosion to the start of failure of the corrosion protecting coating;
τ_t is the transition time duration.

Figure 4 shows both functional equations (2) and (3), i.e. time-dependant corrosion depth expressed in [mm/year], and time-dependant removed/replaced steel amounts expressed in [t] units. Additionally, the time-variant removed/replaced steel amounts over pre-specified areas have been presented for different τ_c, i.e. $\tau_c \in$ [10, 12, 15]years.

Figure 4. Scheme of two different functional approximations for corrosion degradation of the bulk carrier's structure members (d, Q).

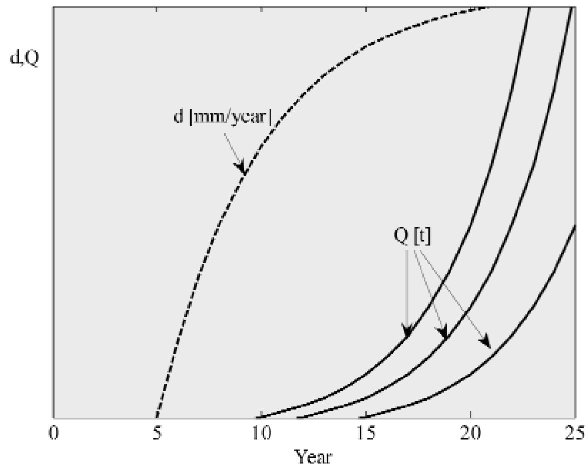
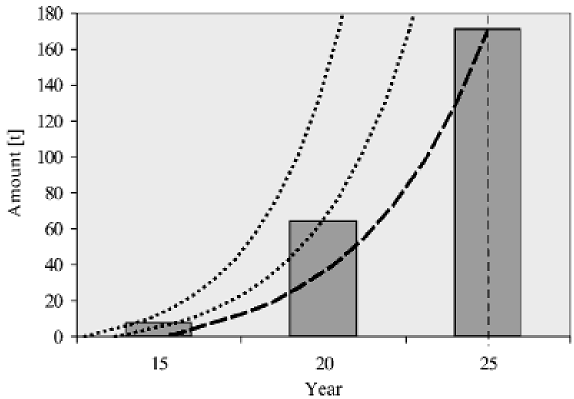


Figure 5. The inner bottom plating degradation: comparison of average removed steel amounts and predicted ones for different τ_c.



The curves Q[t] in Figure 4 have been *transposed* to the scheme of average removed/ replaced steel amounts over bulk carriers' inner bottom plating areas in the case of examined set of seven aging bulk carriers, and the results are shown in Figure 5.

In the case of the experimental set of data collected from seven aged bulk carriers (Figure 5) the predicted Q(t) approximates curve for $\tau_c = 15$ best feats to the average values of steel replaced at 15, 20, and 25 year of ships' exposure to the corrosion process in the marine environment. The inner bottom plating areas were only considered here, since these areas are in the greatest extend exposed to the corrosion. An analog approach might be used in comparing each bulk carrier's member structure and proposed approximated functional equation (3). The proposed equation (3) should be evaluated by the larger amount of the statistical data, being collected by few companies and/or ships' classification societies. In the case of observed bulk carriers' inner bottom plating areas, for $\tau_c = 15$, rather complete steel construction amounts have been replaced at 25th year of the ships' exploitation life. The last noted might be an indicative fact for forthcoming investigations in this domain.

CONCLUSION

In this paper, on the exemplar of a set of aged bulk carriers, Monte Carlo simulation method has been employed in predicting steel amounts that are to be replaced at a certain ships' structure category per year. Some improvements of the results obtained by the usage of *pure* Monte Carlo method have been suggested. The improvements should comprise a kind of "synthetic" or "artificial" interventions in the historical (empirical) simulation input data, in order to increase the frequency of appearing the most common amount of steel (due to the experts experiences) which is to be removed/replaced over the certain bulk carrier structure category (member) area per year. This might be treated as a particular *syncretism* of some quantitative and qualitative simulations analysis in the process of predicting steel amounts that are to be replaced over each longitudinal and transversal element of bulk carriers' structures, caused by the corrosion degradation during the period of the operational life. Toward further, more extensive, investigations in this domain, the larger input data base and its deeper proper segregation of each bulk carrier's structural areas into the considerably smaller segments are necessary.

The paper also proposes a novel approximate, predictive, time-variant functional model for steel amounts that might be replaced/removed over bulk carriers' inner bottom plating locations. The proposed model might be treated as rather original one in comparison to the previously developed several time-variant corrosion wastage depth models. But, it has to be tested (validated) over the larger input statistical data base. Though, the last mentioned is to become the subject of further more rigorous investigations in the wide domain of bulk carriers' hull structures corrosion damages modeling.

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STUDY OF THE GEOGRAPHICAL BOUNDARIES FOR THE FREE USE OF DISPERSANTS

J. Bergueiro[1,4], D. Lindo[1,3], S. Moreno[1,5], J. Calvilla[2], J. Gómez[2] and J. González[2]

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Abstract

Dispersants are chemical agents that reduce the interfacial tension between oil and water in order to enhance the natural process of oil dispersion in sea by generating larger number of tiny droplets that can be entrained permanently into the water column by wave mixing energy.

This study aims to serve as a model to follow when establishing the geographical boundaries for the use of dispersants in order to allow the response authorities to define which dispersion strategy should be take immediately after the incident. To this end, the conclusions of this paper will be based on the comparison between the results of the simulation model AREAS (Bergueiro and Domínguez, 2001), the simulation model DISPERSANTES (Bergueiro and Domínguez, 2001) and the boundaries for the free use of dispersants established by the French research centre CEDRE (Lewis and Merlin, 2006).

Key words: Oil spill, spreading, dispersant, pollutant, contingency planning, simulation model.

INTRODUCTION

When an accidental oil spill occurs, several response options are possible. These possibilities are usually studied though two different approaches; to recover the hydrocar-

[1]Universidad de las Islas Baleares, Palma de Mallorca (Spain). [2]Universidad de La Laguna, email: (garoedi@hotmail.com), Santa Cruz de Tenerife (Spain). [3]Corresponding author. Phd Researcher. CEDRE. Centre de Documentation, de Recherche et d´Expérimentations sur les Pollutions Accidentelles des Eaux. Brest. CEDEX 2 -France. E-mail address: David.Lindo@cedre.fr; latichati@yahoo.es. [4]Profesor Titular, E-mail address: ramonbergueiro@uib.es. [5]Doctora, E-mail address: silvia.moreno@uib.es.

bon or to leave the oil in the environment. This second approach includes the spreading of dispersants and the natural elimination of the pollutant. The appropriate use of one or other option should minimize the impact of environmental pollution.

Before deciding on which response strategy to choose, it is often timely to see whether the response will mitigate the pollution and improve the situation or whether it is better to leave well alone and refrain from responding. This approach is called NEBA (Net Environmental Benefit Analysis). The impact of the dispersed oil has to be less than that of non dispersed oil. Dispersed oil is more dangerous for the aquatic fauna and flora (corals, fish farm water intakes and industrial water intakes) than oil floating on the water surface (Lewis and Merlin, 2006). Defining areas where it is possible to disperse is tantamount to doing a «net environmental benefit analysis» or an «ecological advantage analysis» of dispersant spraying for set scenarios. However, contradictory opinions exist regarding dispersant use, their effect on oil and their environmental impact.

Dispersants are chemical agents that reduce the interfacial tension between oil and water in order to enhance the natural process of dispersion by generating larger number of tiny droplets that, when small enough, can be entrained permanently into the water column by wave mixing energy.

The use of dispersants should be applied rapidly. If the oil weathers, the treatment is less effective. Based on the above considerations and from practical experience, it is evident that response actions using dispersants should be initiated as soon as possible, and every effort should be made to apply the dispersants before significant oil weathering has occurred to improve the probability of success. It should be noted that increased viscosity and water content in an emulsion also affect the ability to treat spilled oil by other response methods. Thus, it is necessary to establish a tests procedure and an intervention plan which provides for:

— The regular testing of the effectiveness of the stored products
— The storage of dispersant in precise places according to available logistics
— The definition of geographical limits beyond which use is permitted

Only certain countries have a clearly defined policy regarding the use of dispersants (Lewis and Merlin, 2006). This study aims to serve as a model to follow when establishing the boundaries for the use of dispersants in order to allow the response authorities to define which dispersion should be take immediately after the incident. To this end, the conclusions of this paper will be based on the comparison between the results of the simulation model AREAS (Bergueiro and Domínguez, 2001) the simulation model DISPERSANTES (Bergueiro and Domínguez, 2001) and the boundaries for the free use of dispersants established by the French research centre CEDRE (Lewis and Merlin, 2006).

METHODS

State of the art

As a result of their different geographic locations, different maritime states of the EU have reached various agreements with their regional neighbours with the aim of dealing with the problem of oil pollution. The major agreements in Europe are:

— The Bonn Agreement (concerning the North Sea)
— The Helsinki Commission (HELCOM) (concerning the Baltic Sea)
— The Barcelona Convention (concerning the Mediterranean Sea)

The French Centre of Documentation, Research and Experimentation on Accidental Water Pollution, CEDRE, established, with the help of French scientific organizations, an old geographical boundary beyond which the use of dispersants was possible (Lewis and Merlin, 2006). Thus, the widespread use of dispersants was not accepted at sea in the following cases:

— In depths of less than 20 m in the North Sea, English Channel and Atlantic
— In depths of less than 50 m in the Mediterranean
— At a distance of less than one nautical mile from the coastline

However, the need has become apparent to modify these limits considering the distance from the coast, depth, biological resources in areas considered, currents and tides. Therefore, as an initial approach, new limits will be defined for oil spills of 10 t, 100 t and 1000 t.

Present and possible role of models

Various chemical and physical processes constrain a number of operational decisions and play a significant role in evaluating potential impacts of whole and dispersed oil on sensitive species or habitats. Models are, therefore, powerful and necessary tools to support decisionmakers during all phases of oil spill planning (Bergueiro and Domínguez, 2001; Bergueiro *et al.*, 2004) response, and assessment. Currently trajectory analysis is a key component of contingency planning (Castanedo *et al.*, 2004) real-time prediction of slick trajectory, size, and thickness, and in natural resource damage assessment. These models could used in real time to support decisionmaking for dispersant use. Thus, their ability to predict the concentrations of dispersed oil and dissolved aromatic hydrocarbons in the water column with sufficient accuracy to aid in spill decisionmaking has yet to be fully determined.

The sensitivity analysis identified that dispersant effectiveness and oil droplet size change are the most important parameters for dispersant application modelling (National Research Council of the National Accademy, 2005). Unfortunately, oil spill models currently available do not simulate physical mechanisms and chemical reactions in order to predict these parameters. Emulsification is also an important process that greatly influences dispersant effectiveness (Reed *et al.,* 1999), M. Predicting emulsification requires accurate oil properties, as well as conducting a detailed mechanistic investigation on emulsification processes and their influence on dispersant effectiveness. It is also important to evaluate turbulence in the open sea and reflect it more accurately in the transport modeling (Reed *et al.,* 1999).

Models show significant progress for supporting real-time spill-response decisions regarding dispersants use; however, models should improved, verified, and then validated in an appropriately designed experimental setting or during an actual spill. Specific steps that should be taken to improve the value of models for dispersant use decisionmaking include:

— Improve the ability to model physical components of dispersed oil behavior (e.g., distribution of horizontal velocities as a function of depth, variations in the vertical diffusivity as a function of depth, sea-surface turbulence, etc.)
— Improve the ability for models to predict concentrations of dissolved and dispersed oil, expressed as specific components or pseudocomponents, that can be used to support toxicity analysis
— Validate how advective transport of entrained oil droplets is modeled through specifically designed flume/tank studies and open-ocean (spill of opportunity) tests.
— Develop an ability to predict the formation of water-in-oil emulsions under a variety of conditions.
— Conduct a sensitivity analysis based on three-dimensional, oil-component, transport and fate models, and develop necessary databases (evaporation, dissolution, toxicity, etc.) for the oil-component based assessment approach

There have been some attempts to incorporate surface flow measurements into real-time oil transport models (Ojo and Bonner, 2002). However, these require preinstallation of data acquisition (e.g., high frequency radar) and transmission systems are currently applicable only to horizontal surface current and diffusion with relatively coarse grid resolution-not for the three-dimensional distributions needed for the three-dimensional modeling (Ojo and Bonner, 2002). The growing availability of ocean observing systems in coastal waters will likely improve the availability of real-time data useful for improved modeling of physical processes.

Method of defining geographical boundaries

Initially, the boundaries are defined based on the minimum depth and distance from the coastline. To this end, the boundaries are drawn on maps of the National Geographic Institute considering only the bathymetry of the continental shelf and the distance from the zero line of marine maps (low tide line). Emerging rocks, islets, islands and ports are also considered. The boundaries are drawn freehand for the whole national coast: Atlantic, Mediterranean and insular.

It is recommended that a standard area with the following characteristics be chosen:

— A high morphological diversity
— Presence of islands or islets around it
— Wealth of fisheries and aquaculture
— Location likely to encounter oil spills because of nearby oil routes (eg. Spanish Finisterre)

RESULTS

Determination of the approximate minimum depth

The thickness of the oil slick will not be uniform and it is difficult to determine it with precision. Research conducted by the Bonn Agreement has led to the adoption of an oil appearance code as shown in table 1 and image 1.

Description Appearance	Layer Thickness Interval (µm)	Litres per km²
1. Sheen (silvery/grey)	0.04 to 0.30	40 – 300
2. Rainbow	0.30 to 5.0	300 – 5 000
3. Metallic	5.0 to 50	5 000 – 50,000
4. Discontinuous True Oil Colour	50 to 200	50 000 - 200 000
5. Continuous True Oil Colour	200 to more than 200	200 000 - More than 200 000

Table 1. Appearance code.

A thickness of 0.1 mm is chosen.

For a layer of oil with a thickness of $0.1 \cdot 10^{-3}$ *m* and surface $S(m^2)$, the volume of oil V will be $0.1 \cdot 10^{-3} \times S(m^3)$

This volume corresponds to a level of 100 ppm of hydrocarbon in the case of total dispersion in the first few meters of the water column.

For the definition of the new limits, it is considered that ecological systems can withstand a temporary toxic effect due to the toxic mixture of oil and dispersant.

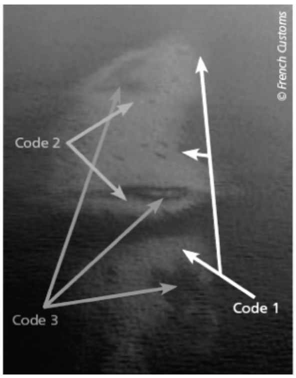

Image 1.

First simulation

The hypothetical scenario consists of a spill of 10,000 t of Arabian Light oil, with a viscosity of 14 mPa.s and showing 25% weathering. It is assumed that the oil is dispersible, and that it is logistically feasible to apply dispersants. The simulation model DISPERSANTES gives the following results:

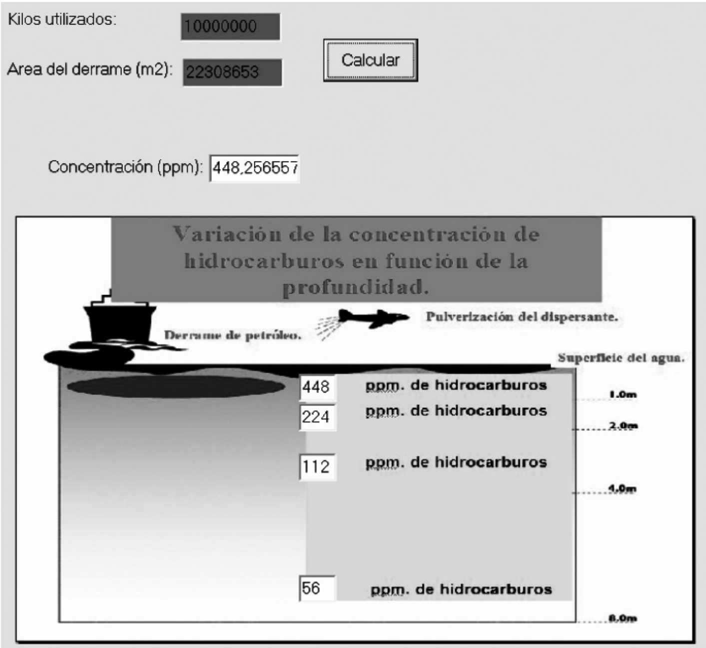

Image 2. Dispersed oil distribution in the water column after treatment

As shown in Image 2, the oil concentration decreases from 400 ppm to 100 ppm in the first four metres deep, just before dropping to 50 ppm at 8 metres.

Measurements taken during sea trials by CEDRE show that in the early stages, the oil is concentrated in the immediate vicinity of the surface: a maximum concentration of oil from 50 to 60 ppm was measured 1 m below the surface for 2-3 hours. For depths of between 1 m and 2.5 m, it was estimated that low concentrations will fall suddenly because of dilution. Therefore, the calculated values and tests at sea are remarkably similar.

Determining the distance from the coast

In order to determine the distance from the coast, a thickness of 0.1 mm was chosen. It is assumed that after spreading dispersant, the slick drops from 0.1 mm thick (ie. 100 μm) to 20 μm thick. Based on the average density of the products normally transported, it is known that a thickness of 20 μm corresponds to $20 g/m^2$ of oil, i.e. $2 \cdot 10^{-5}\ t/m^2$). Based on this data, the minimum distance from the coastline is calculated for oil spills of 10 t, 100 t and 1000 t.

— Spill of 10 tonnes of crude oil:

The area affected by the dispersed slick (S):

$$S = \frac{10t}{2 \cdot 10^{-5} t/m^2} = 5 \cdot 10^5 \, m^2$$

If we consider the layer as circular,

$$S = \pi \cdot R^2$$

Thus,

$$R \cong 400 \, m$$

Using a safety factor of 2.25.

$$R = 2.25 \cdot 400$$

$$R = 900 \, m \Rightarrow R = 0.5 \, MN$$

— Spill of 100 tonnes of crude oil:

Similarly:

$$S = \frac{100t}{2 \cdot 10^{-5} t/m^2} = 5 \cdot 10^6 \, m^2$$

$$R \cong 1300 \, m$$

Using a safety factor of 1.45.

$$R = 1.45 \cdot 1300$$

$$R = 1850 \, m \Rightarrow R = 1 \, MN$$

— Spill of 1000 tonnes of crude oil:

Similarly:

$$S = \frac{1000t}{2 \cdot 10^{-5} t/m^2} = 5 \cdot 10^7 \, m^2$$

$$R \cong 4000 \, m$$

Using a safety factor of 1.15.

$$R = 1.15 \cdot 4000$$

$$R = 4600 \, m \Rightarrow R = 2.5 \, MN$$

Note that safety factors decrease as we move away from the coast and are set arbitrarily on the basis of experience gained by CEDRE in such operations.

Second simulation

The hypothetical scenario consists of a spill of 10 t of gasoline, equivalent to 13.5 m^3. Although gasoline has a very high evaporation rate, which normally would discourage its dispersion treatment, this oil is chosen here because it has a very high spreading rate and, consequently, it will reach a larger area and it will be the most unfavourable dispersion scenario. It is assumed that the product is dispersible, and that it is logistically feasible to apply dispersants. The simulation model AREAS gives the following results:

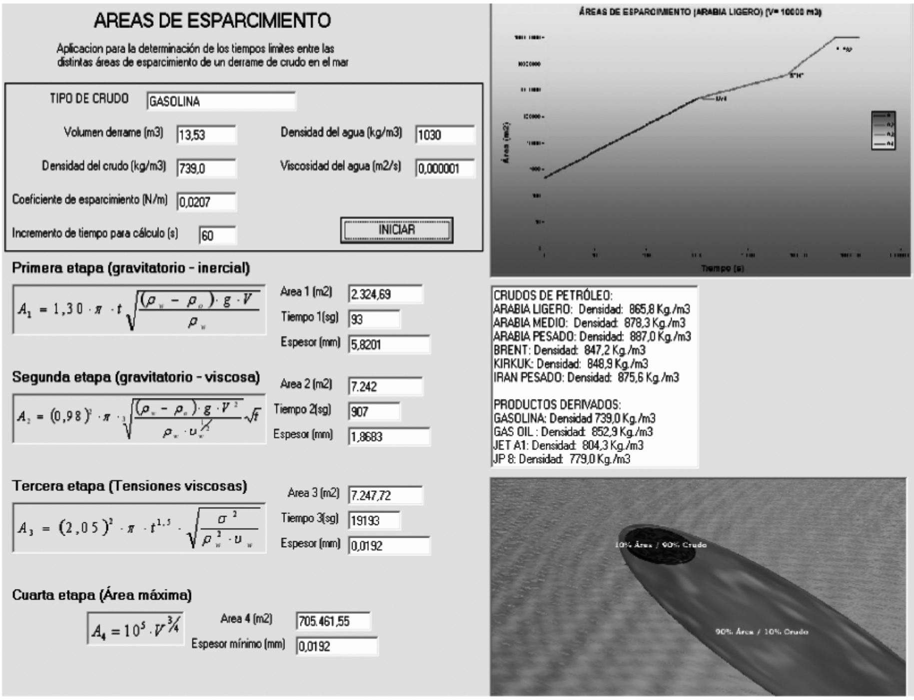

Image 3. Spreading areas.

Based on the Areas model of Fay (1971) concerning the three phases of oil spreading, it the maximum area will be used. The choice of one area or the other depends on the time after which the dispersant application begins. Considering the most unfavourable case, after 5.3 hours the maximum area corresponds to 705,000 m^2 and the thickness of the layer is 19.2 μm. Therefore, considering the slick as circular and applying a safety factor of 2.25 we obtain $R = 1066\ m \Rightarrow R = 0.58\ MN$

Third simulation

The hypothetical scenario consists of a spill of 100 t of gasoline, equivalent to 135.3 m^3. Similarly to second simulation, gasoline is chosen because it entails the most unfavourable dispersion scenario. Under these conditions the maximum area corresponds to 3,967,100 m^2 and the thickness of the layer is 34.1 μm. Therefore, considering the slick as circular and applying a safety factor of 1.45 we obtain $R = 1630\ m \Rightarrow R = 0.9\ MN$

Fourth simulation

The hypothetical scenario consists of a spill of 1000 t of gasoline, equivalent to 1353 m^3. Similarly to third simulation, gasoline is chosen because it entails the most unfavourable dispersion scenario. Under these conditions the maximum area corresponds to 22,308,652 m^2 and the thickness of the layer is 60.6 μm. Therefore, considering the slick as circular and applying a safety factor of 1.15 we obtain $R = 3.065\ m \Rightarrow R = 1.8\ MN$

Setting limits based on an analysis of the environmental impact

As a second stage, it is necessary to seek the support of Maritime Affairs to take stock of the sensitive areas of the coastline in the following domains:

— Aquaculture areas
— Deposits of benthic species
— Spawn areas
— Limitations and reserves

The available data will be reported to the National Geographic Institute maps and the limits defined will be adjusted in terms of the protection of sensitive sites. The limits of such places will be considered as the “zero line.” From here, the limits were defined considering the minimum distance and depth calculated in the first stage.

CONCLUSIONS

1) If 10 tonnes of crude oil are spilt in a 5 m deep water column, it is estimated that the expected oil concentration will be 20 ppm after treatment. As the slick of 10 t oil is relatively small, the area affected is not very large and 20 ppm is rapidly diluted.
2) If 100 tonnes of crude oil are spilt in a 10 m deep water column, it is estimated that the expected oil concentration will be 10 ppm in the water column after treatment. This weak concentration will not significantly affect the environment during the time necessary for effective dilution by currents.

3) If 1000 tonnes of crude oil are spilt in a 15 m deep water column, it is estimated that the expected oil concentration will be 6.5 ppm in the water column after treatment. If there is no bathymetric data for a depth of 15 m, limits will be outlined considering the bathymetry of 10 m and 20 m.
4) By means of the model AREAS, it has been estimated that in order to disperse a 10 t oil spill without affecting the coast, the slick must be located further than 0.6 NM from the low tide line of marine maps.
5) By means of the model AREAS, it has been estimated that in order to disperse a 100 t oil spill without affecting the coast, the slick must be located further than 1 NM from the low tide line of marine maps.
6) By means of the model AREAS, it has been estimated that in order to disperse a 1000 t oil spill without affecting the coast, the slick must be located further than 2 NM from the low tide line of marine maps.
7) If the currents may cause the oil spill to contaminate a sensitive area, it will be necessary to extend the limits against the current.
8) If the place has stationary sensitivity, it will be necessary to identify and determine the boundaries depending on the season.

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ESTUDIO DE LOS LIMITES GEOGRÁFICOS PARA LA LIBRE UTILIZACIÓN DE DISPERSANTES

Resumen

Los dispersantes son agentes químicos que reducen la tensión superficial entre el hidrocarburo y el agua con el fin de favorecer el proceso natural de dispersión del crudo en el mar a través de una generación de pequeñas gotas que pueden ser incorporadas permanentemente en la columna de agua con la ayuda de la energía de mezcla de las olas.

Este estudio pretende servir como un modelo a seguir para establecer los límites geográficos para la libre utilización de dispersantes y así ayudar a que las autoridades competentes de la lucha contra la contaminación por hidrocarburos definan qué estrategia de dispersión debe tomarse inmediatamente después del incidente. Siguiendo este fin, las conclusiones de este artículo se basarán en la comparación de los resultados del modelo de simulación AREAS (Bergueiro y Domínguez, 2001), el modelo de simulación DISPERSANTES (Bergueiro y Domínguez, 2001) y los límites geográficos para la libre utilización de dispersantes establecidos por el centro de investigación francés CEDRE (Lewis y Merlin, 2006).

METODOLOGÍA

Estado del arte

A raíz de sus diferentes localizaciones geográficas, los diferentes estados marítimos de la UE se han volcado a acordar diversos acuerdos regionales con sus vecinos con la finalidad de abordar los problemas de la contaminación marina por hidrocarburos. Los mayores acuerdos en Europa son:

— El acuerdo de Bonn (concerniente al Mar del Norte)
— La comisión de Helsinki (Helcom) (concerniente al Mar Báltico)
— La convención de Barcelona (concerniente al Mar Maditerráneo)

El centro francés de documentación, investigación y experimentación sobre la contaminación accidental de las aguas, CEDRE había establecido con la ayuda de organismos científicos franceses un límite geográfico más allá del cual era posible la utilización de dispersantes sin riesgos para el medio marino. Así, la utilización masiva de dispersantes no estaba aceptada en mar para los siguientes casos:

— En fondos inferiores a 20 m en Mar del Norte, Mancha y Atlántico
— En fondos inferiores a 50 m en el Mediterráneo
— A menos de una milla náutica de las costas

Sin embargo, surge la necesidad de modificar estor límites considerando la distancia a la costa, la profundidad, los recursos biológicos de las zonas consideradas, las corrientes y las mareas. De esta manera se definirán nuevos límites para vertidos de 10 t, 100 t y 1000 t.

Método de definición de los límites geográficos

Inicialmente, se definen los límites a partir de la profundidad mínima y de la distancia a la costa. Para ello, se trazan los límites sobre los mapas del Intituto Geográfico Nacional considerando exclusivamente la batimetría de la plataforma continental y la distancia a la línea cero de los mapas marinos (línea de bajamar). Se consideran también las rocas emergentes, los islotes, las islas y los puertos. Los límites se trazan a mano alzada sobre toda la costa nacional; atlántica, mediterránea e insular.

Es recomendable escoger una zona como estándar que presente las siguientes características:

— Una elevada diversidad mofológica
— Presencias de islas u islotes a su alrededor
— Riqueza en actividades de pesca y acuicultura
— Situación geográfica susceptible a vertidos debido a la proximidad de rutas petroleras (ie, el finisterre español)

CONCLUSIONES

1) Si se vierten 10 toneladas de petróleo en una columna de agua de 5 m de profundidad, se estima que la concentración de hidrocarburo esperada después del tratamiento será de 20 ppm. Como el vertido de 10 t de petróleo es relativamente pequeño, el área afectada no es muy extensa y los 20 ppm se diluyen rápidamente.
2) Si se vierten 100 toneladas de petróleo en una columna de agua de 10 m de profundidad, se estima que la concentración de hidrocarburo esperada después del tratamiento será de 10 ppm. Esta débil concentración no afectará al medio ambiente durante el tiempo necesario para una dilución efectiva llevada a término por las corrientes.
3) Si se vierten 1000 toneladas de petróleo en una columna de agua de 15 m de profundidad, se estima que la concentración de hidrocarburo esperada después del tratamiento será de 6,5 ppm. Si no existen datos de batimetría para una profundidad de 15 m, los límites se establecerán considerando la batimetría de 10 m y 20 m.
4) Mediante el modelo AREAS, se ha estimado que para dispersar 10 t de petróleo sin que se afecte a la costa, el vertido debe estar situado a más de 0.6 MN de la línea de bajamar de la carta náutica

5) Mediante el modelo AREAS, se ha estimado que para dispersar 100 t de petróleo sin que se afecte a la costa, el vertido debe estar situado a más de 1 MN de la línea de bajamar de la carta náutica.

6) Mediante el modelo AREAS, se ha estimado que para dispersar 1000 t de petróleo sin que se afecte a la costa, el vertido debe estar situado a más de 2 MN de la línea de bajamar de la carta náutica.

7) Si las corrientes pueden ocasionar que el vertido de hidrocarburo contamine una zona sensible, será necesario extender los límites contra el sentido del que procede contra la corriente

8) Si el lugar tiene una sensibilidad estacionaria, será necesario identidicar y determinar los límites en función de la estación del año.

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A SIMULATION FRAMEWORK FOR OPTIMIZING TRUCK CONGESTIONS IN MARINE TERMINALS

M. Kiani[1,2], J. Sayareh[1,3], S. Nooramin[1,4]

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Abstract

One of the prominent issues that marine terminal operators are seeking to address is to how effectively reduce the truck turn-around times. The time a truck spends at a terminal for loading and/or unloading cargo is a real cost scenario which will affect the overall cost of the container trade.

This research uses the Taylor II simulation software to develop a queuing based simulation methodology that may assist the terminal operators in minimizing truck congestions and smoothing the gate operation to reduce truck turn-around times at marine terminals. The main goal of this paper is to help to reduce the average number of trucks in queues and average trucks' waiting times in both entrance and exit gates of the ports.

Key words: Simulation Framework, Truck Congestions, Optimization, Marine als, Truck turn-around times

INTRODUCTION

In general, container terminals can be described as open systems of material flow with two external interfaces. These interfaces are the quayside designed for loading and unloading of ships, and the landside where containers are loaded and unloaded on/off the trucks (Steenken *et al.*, 2004). Most terminals are taking measures to increase their throughput and capacity by (Huynh and Walton, 2005):

[1]Chabahar Maritime University, Tel. +9854522220020, Rigi Blvd. 9971756499, Chabahar (Iran). [2]Senior Lecturer, E-mail address: mansoorkiani@googlemail.com. [3]Senior Lecturer, E-mail address: j.sayareh@gmail.com. [4]MSc in Maritime Transport. Corresponding author: E-mail address: saeid.nooramin@yahoo.com.

— Introducing new technology
— Optimizing equipment dwell-times
— Increasing storage density
— Optimizing ship turn-around times
— Optimizing truck turn-around times

A great variety of container terminals exists mainly depending on which type of handling equipment are combined to form a terminal system. Koshnevis and Asef-Vaziri (2000) define three performance analysis variables including throughput, space utilization and equipment utilization. Kozan (2000) discusses the major factors influencing the transfer efficiency of seaport container terminals by developing a network model. Similar studies in this field are carried out by Nam and Ha (2001), Lie *et al.* (2002), Vis and de Koster (2003), and Murty *et al.* (2003). Nishimura *et al.* (2009) implement Lagrange method for optimizing the container yard operation.

Berth planning problems may be formulated as different combination of optimization problems depending on the specific objectives and restrictions that have to be observed. Kim and Kim (2002) have discussed a method of routing yard-side equipment during loading operations in container terminals by an encoding method. Park and Kim (2003) have used a mixed-integer-programming model which simultaneously scheduled berth and container cranes. Legato and Mazzo (2001), Nishimura *et al*. (2001), Imai *et al*. (2001 and 2005), Moorthy and Teo (2006) have all carried out numerous studies on berth planning problems. Lee and Chen (2009) optimize the berth operation by evaluating different arrival patterns.

Nowadays, the logistics activities, especially at large container terminals, have reached a degree of complexity that further improvements are required the interaction of scientific solutions. Simulation models have become the viable tools for decision-making in port activities. Kia *et al.* (2002) have investigated the role of computer simulation in evaluating the performance of a container terminal in relation to its handling techniques and the impact it makes on the capacity of terminal. Parola and Sciomachen (2005) have presented a discrete event simulation modelling approach related to the logistic chains of an intermodal network. Bielli *et al.* (2006) have provided a help-tool in a port decision support system implementing simulation *via* Java environment. Froyland *et al.* (2008) have presented an algorithm to manage the container exchange facility, including the allocation of delivery locations for trucks and other container carriers. Zeng and Yang (2009) have developed a simulation optimization method for scheduling the loading operations in container terminals.

The time a truck spends at a terminal for loading and/or unloading of the cargo is a real cost scenario which affects the overall cost of the container trade. Han *et al.* (2008) have studied a storage yard management problem in a transhipment hub where the loading and unloading activities are both heavy and concentrated with the aim of reducing traffic. Historically, truck turn-around times have received a very little attention from terminal operators because landside congestions have never been a barrier to their smooth operations. Truck turn-around times are the times that a truck takes to complete an activity such as picking up an import container. As shown in the studies conducted by Palmer (1996), Kim and Kim (1998), Kim *et al.* (2000), Regan and Golob (2000), Klodzinski and Al-Deek (2002), Mongelluzzo (2003), and Huynh and Walton (2005), by optimising the truck turn-around times and thereby the landside shipping cost, the terminals would gain a competitive advantage in the industry. In the research carried out by Jula *et al.* (2005), the container movement by trucks with time constraints at both origins and destinations was modeled as an asymmetric multi-Travelling Salesmen Problem with time windows which often referred to as the full-truck-load problem. Murty *et al.* (2005) have described a variety of inter-related decisions made during daily operations at a container terminal. Their goal was to minimize the waiting time of customer trucks. Jinxin *et al.* (2008) have proposed an integer programming model for containers handling, truck scheduling and storage allocation as a whole. Trucks are spending more and more idling time at ports because of congestions. There are two common measures that terminal operators are looking at to overcome this problem. First, adding more yard cranes; and second, employing the aid of computer technologies such as the truck appointment systems (Huynh and Walton, 2005). The main focus of this research is on the second alternative in which the idea is to flatten the gate activity to an efficient level so as to reduce the trucks' queuing time.

Consequently, the objective of this research is to minimize the trucks' congestions at the main gates of the Shahid Rajaee Port Complex, the major Iranian seaport, and hence to reduce the truck turn-around times. Even though the case study is unique and distinctive of its kind, the general processes and characteristics are similar to a typical container terminal as shown in Figure 1.

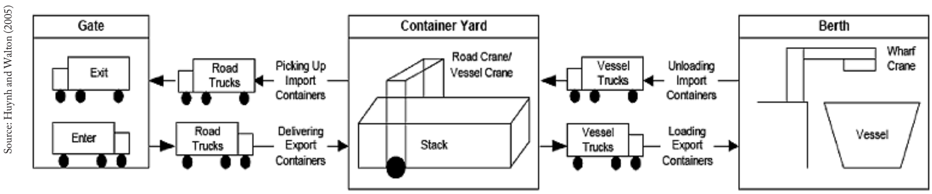


Figure 1. Process of loading/discharging operation in marine terminals.

Achieving this objective and finding the bottlenecks, the following three main patterns will be examined:

1. Arrival patterns of trucks at entrance,
2. Departure patterns of trucks at exit, and
3. Service patterns of weighbridges.

Accordingly, the study will provide a new methodology using the Taylor II simulation software which will attempt to integrate all functions needed for a simulation study by combining all determining parameters in a simple manner and a high flexibility with ease-of-use without making concessions to the functionality of the tasks.

After perusing the queue and waiting time histograms for mentioned patterns, for both entrance and exit, three different solutions would be proposed and modelled. The challenging issues inherent truck congestion in marine terminals, coupled with the limitation of existing research, motivate this study.

PROBLEM STATEMENT

The Shahid Rajaee Port having 26 specialized berths can serve 22 merchant vessels and 2 tanker ships, simultaneously. The port is equipped with 6 main automatic weighbridges in following patterns:

— 2 are located near the main entrance of the gate complex,
— 2 are located near the exit gate, and,
— 2 are located at the transit yard where only one of them is operational.

Based on the number of Bills of Ladings (B/Ls) analysed, Table 1 represents the traffic of trucks in the port of Shahid Rajaee during the period of study (Mar.-Jun. 2009).

Table 1. Traffic of trucks in the Port of Shahid Rajaee

Item	Trucks	Chassis
From Shahid Rajaee	204,579	77,833
To Shahid Rajaee	153,184	64,374

To help identifying the bottlenecks in the process of loading and/or unloading operation of trucks, this section will also study the main patterns of trucks' turnaround times, including:

— Arrival pattern of trucks at the main entrance of the gate complex,
— Service pattern of weighbridges located at the both entrance and transit gates,
— Departure patterns of trucks at main gate exit, and
— Service patterns of weighbridges located at the main exit of the gate complex.

Arrival Patterns of Trucks at the Main Gate Entrance

Trucks arriving at the main gate entrance are generally categorized in four groups, including; 1) empty trucks calling at the loading points, 2) trucks carrying export cargoes, 3) trucks carrying the transit cargoes and 4) urban trucks entering the terminal.

Based on the data collected from more than 1500 trucks in one of the busiest working days, the arrival pattern of trucks is confirmed to the Lognormal distribution with an average of 17.56 sec. per truck. From all arrivals, 65% were weighed at the gate entrance. Amongst remaining trucks, 45.3% were weighed inside the port area and others were the urban trucks which were not weighed. Also, amongst all arrivals, 49.6% were the empty chassis which were not weighed.

Service Pattern of Weighbridges

Data analysis showed that service patterns of weighbridges located at the entrance, transit and gate exits are compatible with Beta distribution with an average of 68.66 sec. per truck. After the process of weighting, all trucks are controlled by custom authorities inside the port.

Departure Patterns of Trucks at the Main Exit of the Gate Complex

Departure trucks are categorized in four groups including 1) those carrying the imported cargoes, 2) container carriers, 3) trucks carrying the transit cargoes, and 4) the empty tucks discharging their cargo in the port. The departure patterns of trucks are considered to confirm to a negative exponential distribution with an average of 24.27 sec per truck.

SIMULATION MODEL DEVELOPMENT

The Taylor II program designed by F&H Simulation Inc. is employed in this study. The Taylor II program is a menu-driven simulation package mainly used in manufacturing, warehousing, and material handling industries. The program is specially developed for the analysis and evaluation of quantitative problems with a dynamic character (Nordgren, 1998). The program enables simulation of discrete event systems with discrete entities.

A proper simulation demands three groups of parameters:

— Element parameters describing the behaviour of elements, including capacity and properties of customers (arrivals and departures),
— Job parameters including properties of servers such as processing, transporting and storing, and
— Stage parameters including supplementary information about customers.

The following assumptions are considered during this study:

— Traffic is uniformly distributed over the entire yard for import and export cargoes,
— The port is considered to be operational for 365 days/year and 24 hours/days,
— All containers have the same length,
— No collision among trucks and between trucks and cranes,
— No double moves, and
— The characteristics of the facilities (weighbridges) are the theoretical figures given by manufacturers and do not change during the study.

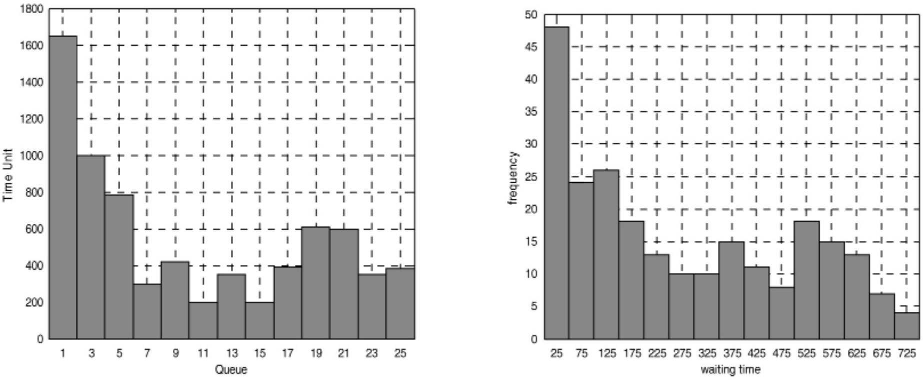
This section of study follows with modelling of the case study based on the required parameters. After perusing the queue and waiting time histograms (Predefined graphs) for patterns mentioned earlier and finding out the bottlenecks involved in the processes of entrance and gate exits and weighbridges, it tries to eliminate the probable defects in the system.

Achieving this purpose, three different solutions would be proposed and modelled for both the entrance and the gate exits, respectively.

Simulating the Model of the Main Entrance of the Gate Complex and Transit Weighbridge

At the first step, the properties of queue at the gate entrance and transit weighbridge should be identified. Figures 2 and 3 represent the queue and waiting histograms for main gate entrance and transit weighbridge, respectively.

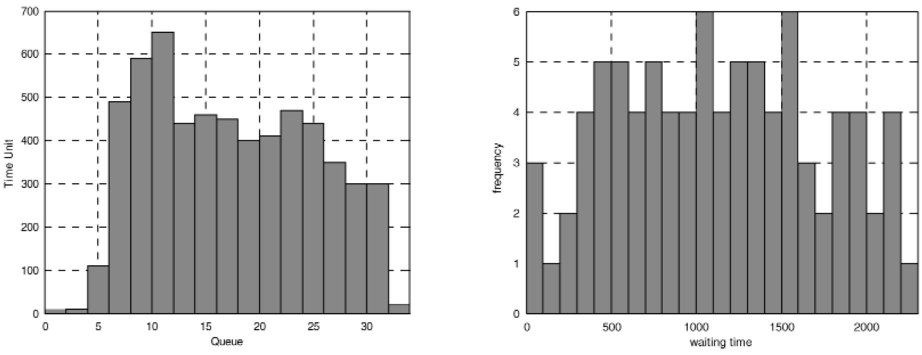
Figure 2. Congestions at the main gate entrance in the busy working times.



Min. Val.: 0.00 / Max. Val.: 25.00 / Average: 9.31

Min. Val.: 0.00 / Max. Val.: 727.60 S / Average: 274.52 S

Figure 3. Congestions at transit weighbridge in the busy working times.



Min. Val.: 0.00 / Max. Val.: 32.00 / Average: 16.98

Min. Val.: 0.00 / Max. Val.: 2234.50 S / Average: 1130.23 S

Simulation results showed that the two weighbridges of gate entrance are 84% and 54% busy, respectively. Transit weighbridge is also 82% busy at the peak hours of working days.

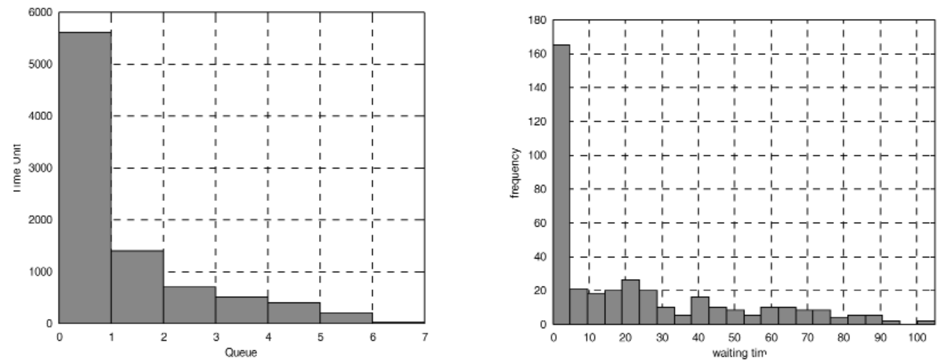
To reduce truck congestions at the gate entrance, three models have been designed and simulated. They include:

— Weighting trucks where drivers do not get off their vehicles,
— Installing an extra weighbridge at the gate entrance, and
— Weighing empty chassis with two transit weighbridges.

Trucks are weighed where drivers do not get off their vehicles

Generally, drivers get off their trucks for Custom and port formalities. This model proposes a system in which drivers remain in vehicles during the weighing process. This is possible with a little change in control room of weighbridges. In this case, service patterns of weighbridges of gate entrance will be compatible with Logistic Distribution requirements with an average of 36.80 sec. per truck. Figure 4 represents the queue and waiting histograms for these weighbridges.

Figure 4. Congestion in weighbridges of entrance gate in busy working times (First model).



Min. Val.: 0.00 / Max. Val.: 6.00 / Average: 0.80

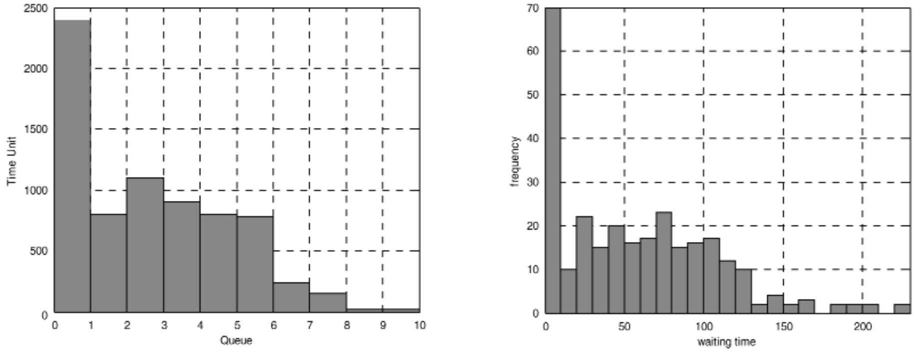
Min. Val.: 0.00 / Max. Val.: 103.20 S / Average: 20.21 S

In this new pattern, the two weighbridges of the gate entrance will be 77% and 68% busy.

Installing an Extra Weighbridge near the Gate Entrance

This model proposes that an additional weighbridge embeds near the two weighbridges at the gate entrance, thus all arrival trucks would be weighed in by three weighbridges. The queue and waiting histograms of these weighbridges are shown in Figure 5.

Figure 5. Congestions in weighbridges of gate entrance in busy working times (Second model).



Min. Val.: 0.00 / Max. Val.: 9.00 / Average: 2.13

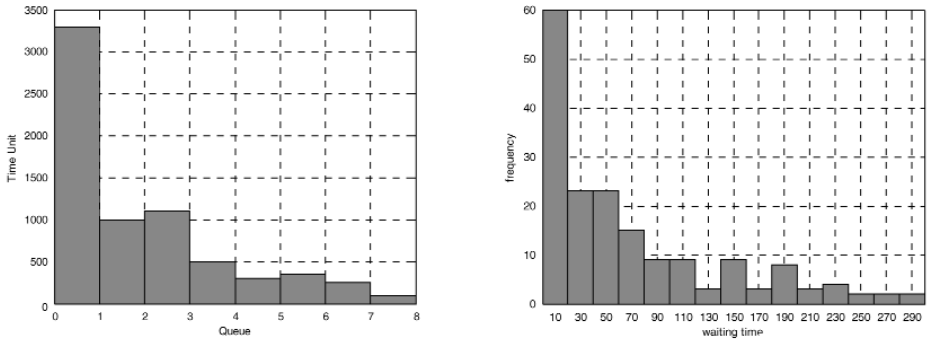
Min. Val.: 0.00 / Max. Val.: 255.50 S / Average: 54.00 S

Simulation results show that these weighbridges will be 88%, 85% and 92% busy.

Weighing Empty Chassis with Two Transit Weighbridges

The third model proposes that both of the transit weighbridges become active and all empty chassis are directed to these weighbridges for weighing. Implementing this model will decrease truck congestions in both the entrance and transit weighbridges. Figure 6 shows the effect of this model on congestions in weighbridges of gate entrance.

Figure 6. Congestions of weighbridges at the gate entrance in the busy working times (Third model).

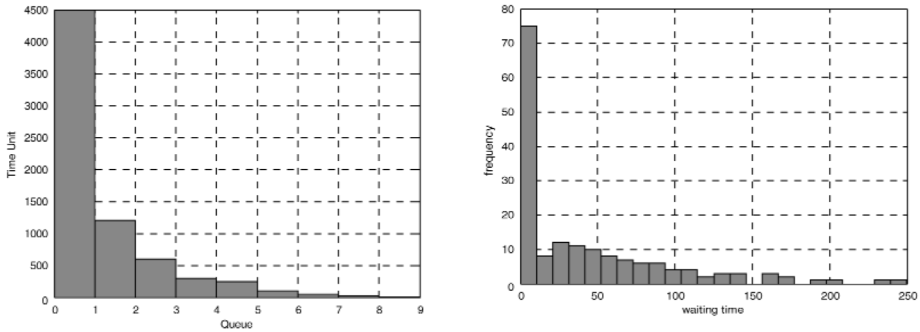


Min. Val.: 0.00 / Max. Val.: 7.00 / Average: 1.48

Min. Val.: 0.00 / Max. Val.: 286.40 S / Average: 62.50 S

The two weighbridges at the gate entrance are found to be 84% and 79% busy. The effect of this model on congestions in transit weighbridges is shown in Figure 7.

Figure 7. Congestions at the transit weighbridges in the busy working times (Third model).



Min. Val.: 0.00 / Max. Val.: 8.00 / Average: 0.86

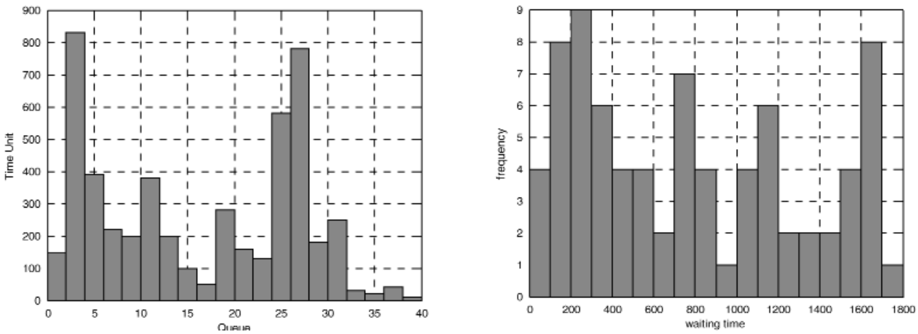
Min. Val.: 0.00 / Max. Val.: 242.50 S / Average: 38.45 S

In the third model, transit weighbridges found to be 69% and 79% busy.

Simulating the Main Gate Exit

As mentioned earlier, there are two active weighbridges at the main gate exit. The bottlenecks at the gate exit, the queue and waiting histograms of trucks in these weighbridges are identified and shown in Figure 8.

Figure 8. Congestions at the weighbridges of gate exit in busy working times



Min. Val.: 0.00 / Max. Val.: 38.00 / Average: 15.90

Min. Val.: 0.00 / Max. Val.: 1709.60 S / Average: 777.39 S

Simulation results showed that the two weighbridges at the gate exit are busy 99% and 98%, respectively in the peak hours of working days.

For modelling the gate entrance and transit weighbridges, three simulation models have been proposed for reducing truck congestions. These include:

— Weighting trucks where drivers do not get off their vehicles,

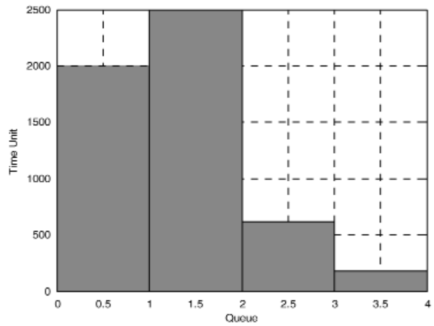
— Installing an extra weighbridge at the gate exit, and
— Weighing vehicles carrying container with transit weighbridge

This section follows with evaluating the effects of proposed models on reducing truck congestions in gate exit.

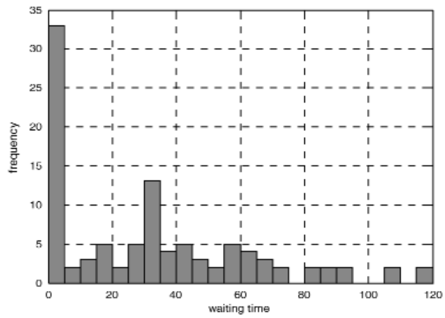
Trucks are Weighed where drivers do not get off their vehicles (Gate Exit)

This model proposes a system in which drivers remain in vehicles during the weighing process. It will be simply possible with a little change in control room of weighbridges. Same as the proposed model for gate entrance, service pattern of weighbridges of the gate exit will also be compatible with Logistic Distribution requirements with an average of 36.80 sec. per truck. Figure 9 represents the queue and waiting histograms for these weighbridges.

Figure 9. Congestions of weighbridges at the gate exit in busy working times (First model).



Min. Val.: 0.00 / Max. Val.: 3.00 / Average: 0.45



Min. Val.: 0.00 / Max. Val.: 115.80 S / Average: 27.19 S

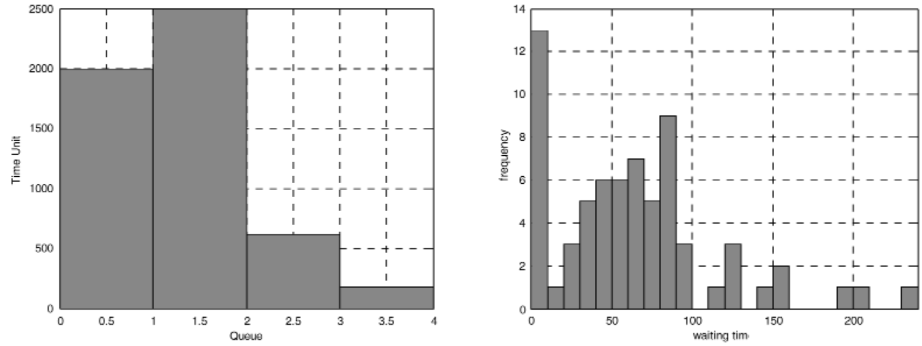
Weighed trucks should refer directly to the parking area for Customs' controls. The first and second weighbridges at the gate exit are found to be 58% and 90% busy.

Installing an Extra Weighbridge Near the Gate Exit

In this case, an extra weighbridge should be installed in gate exit near the previous two weighbridges and all departure trucks should weigh by these weighbridges. Figure 10 shows the queue and waiting histograms for these weighbridges.

The first and second weighbridges are found to be 99% and 91% busy in the new model. The extra weighbridge which is considered only for using at peak hours of traffic is 64% busy.

Figure 10. Congestions in weighbridges of gate exit in busy working times (Second model).

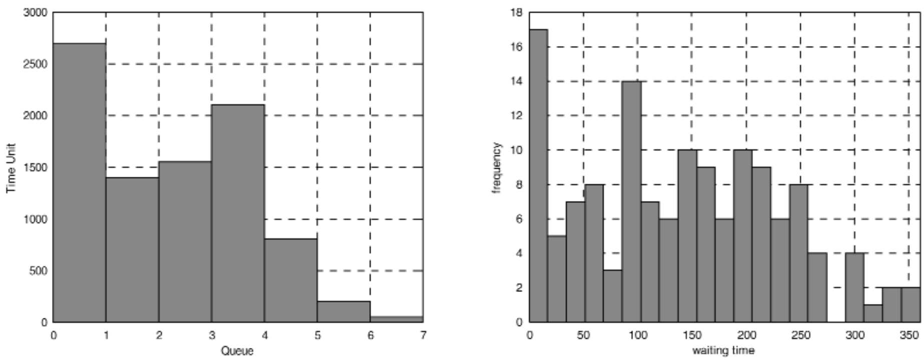


Min. Val.: 0.00 / Max. Val.: 3.00 / Average: 0.81   Min. Val.: 0.00 / Max. Val.: 232.30 S / Average: 63.37 S

Weighing Vehicles Carrying Container with Transit Weighbridge

The third model proposes that the transit weighbridge only to serve the trucks that carry containers. Other trucks should be weighed by weighbridges at the gate exit. Queue and waiting histograms for transit weighbridge are shown in Figure 11.

Figure 11. Congestions in transit weighbridge in busy working times (Third model).



Min. Val.: 0.00 / Max. Val.: 6.00 / Average: 1.73   Min. Val.: 0.00 / Max. Val.: 352.00 S / Average: 133.02 S

In this pattern, the first and second weighbridges at the gate exit found to be 99% and 97% busy. Also, the transit weighbridge is found to be 84% busy.

DATA ANALYSIS

Number of queuing lines and average waiting time of customers are regarded as the main parameters of a queuing system. Following table represents the results of implementing the proposed models and their effects on reducing the truck congestions in the port area and provides a comparison among these models.

Table 2. Simulation results for proposed models

Item			Present model	Proposed model			Congestions Reduction (%)		
				First	Second	Third	First	Second	Third
Weighbridges of gate entrance	Queuing number	Max. (Que.)	25	6	9	7	76	64	72
		Ave. (Que.)	9.31	0.8	2.13	1.48	91	77	84
	Waiting time	Max. (Sec.)	727.6	103.2	225.5	286.4	86	69	61
		Ave. (Sec.)	274.52	20.21	54	62.5	93	80	77
Transit weighbridge	Queuing number	Max. (Que.)	32	—	—	8	100	100	75
		Ave. (Que.)	16.98	—	—	0.86	100	100	95
	Waiting time	Max. (Sec.)	2234.5	—	—	242.5	100	100	89
		Ave. (Sec.)	1130.23	—	—	38.45	100	100	97
Weighbridges of gate exit	Queuing number	Max. (Que.)	34	3.5	3.33	6.33	89	90	81
		Ave. (Que.)	15.56	0.6	0.77	2.77	96	94	82
	Waiting time	Max. (Sec.)	1667.9	123.2	234.4	411.46	93	86	83
		Ave. (Sec.)	770.07	29.01	61.01	174.37	97	92	75

As illustrated in Table 2, the first model resulted the most reductions in the truck congestions at the entrance and gate exits and also at the transit weighbridge. Same as the first model, using the second proposed model, the truck congestions in the transit area is totally eliminated, even though it is considered as the second priority among all models. In comparison with the first and second models, there is less reduction in truck congestions in the third model which assigns the transit weighbridge to empty chassis and container carriers.

CONCLUSIONS

Trucks are spending more and more idle times at ports because of congestions that impose additional costs on port authorities, carriers and the supply chain as a whole. The main idea behind this research was to flattening the gate activities to an efficient level to reduce the trucks' queuing time.

The objective of this research was to minimize truck congestions at the main gates of Shahid Rajaee Port and reducing the truck turn-around times in a prevailing queuing system. Achieving this purpose and finding the bottlenecks, three main patterns including 1) arrival patterns of trucks in entrance, 2) departure patterns of trucks in exit and 3) service patterns of weighbridges have been specified and modelled using the Taylor II simulation software.

After perusing the queue and waiting time histograms for the above patterns and for both the entrance and exit gates, three different solutions were proposed and modelled.

Among all models, implementing the first model which simply weighs the trucks where drivers do not get off their vehicles during weighing process has resulted the highest reductions in the trucks' congestion times as successfully been tested in many modern ports such as Southampton, Felixtow, Thames Port, Liverpool, Kobe and Singapore. Installing two extra weighbridges at both of the entrance and gate exits, which is more investable in comparison with the first model, has shown to be the second priority and hence ranked the second between the three models. Finally, the less priority has been given to the third model that assigns the transit weighbridge for specific vehicles such as empty chassis and container carriers.

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INNOVATION IN SPANISH PORT SECTOR

B. Blanco[1,3], C. Pérez-Labajos[1,4], L. Sánchez[1,5], A. Serrano[2,6], M. López[2,7] and A. Ortega[1,8]

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Abstract

Globalization has generated a dramatic increase in freight traffic worldwide and, in particular, in maritime transport. In response to increasing load capacity requirements, there has been a steady increase in the size of the international merchant fleet, accompanied by a parallel increase in new requirements for ports. This has raised the need for ports to innovate.

If countries want to be competitive, they need a port system that allows them to be part of international supply chains. In addition, each individual port must be competitive with the other ports operating within their national port system. Therefore, competitiveness and competition must be understood from two perspectives, international and national.

This paper analyzes the perception of Spanish Port Authorities on innovation in the national port system. The goal is to establish the innovative activities that are perceived as the most important, those in which there has been an increased effort, and the obstacles facing innovation. These factors have been assessed using the Rasch methodology.

Key words: Innovation, ports, Rasch.

INTRODUCTION

Today, innovation is one of the most influential phenomena worldwide. The continued increase in spending in R & D, both by companies, countries and international agencies, is, to a greater or lesser extent, proof of this.

[1] Ocean and Coastal Economics and Management R&D Group. University of Cantabria. Gamazo 1. 39004 Santander. Spain. [2] Dinámica Estratégica R&D Group. University of Cantabria. Avda Los Castros s/n. 39005 Santander. Spain. [3]Corresponding author: E-mail address blancob@unican.es Tel. +34 942 201897 Fax +34 942 201890 Postal address: Departamento de Administración de Empresas. Facultad de Ciencias Económicas y Empresariales. Avda Los Castros s/n. 39005 Santander. Spain. [4]E-mail address: clabajos@unican.es [5]E-mail address: lidia.sanchez@alumnos.unican.es [6]E-mail address: ana.serrano@unican.es [7]E-mail address: concha.lopez@unican.es [8]E-mail address: andres.ortega@unican.es

Innovation can be defined as "the introduction of a new product, a new production method, a new market, the discovery of new supplies of raw materials in manufactured products, and even the emergence of a new sector or redirection of an existing one "(Schumpeter, in Solé 2008 p.14). It is also one of the key drivers in improving social welfare and a crucial factor in the growth and survival of long-term business (Schumpeter, 1939, Baumol 2002). It is also considered a key element for achieving the sustainable development of economies (OECD).

The development of innovation can take place internally (internal development within the company) or externally (within the market) (Veugelers and Cassiman, 1999; Cassiman, 2004, Cassiman and Veugelers, 2006). Some authors identify a third hybrid form (Pisano, 1990) which consists of the development of innovation through cooperation between various parties (Navarro, 2002; Hull, 2003, Chen and Yuan, 2007).

That said, one might ask, "what are the main reasons that lead a company to innovate?" From a microeconomic perspective, the development of new products or processes lead to the improvement of the products and services offered by a company and the use of fewer resources in the production process. This ensures greater value creation by the company and a reduction in production costs (Mulet, 2005).

On the other hand, from a macroeconomic perspective, innovation is a response to the competitiveness that exists in an increasingly globalized world. The OECD defines competitiveness as the degree to which, under free market conditions, a country can produce goods and services that go beyond the consideration of international competition and, simultaneously, serve to maintain the sustained growth of national income (Mulet, 2005). Therefore, the survival of a company may only be possible if there is innovation.

Why is innovation necessary for ports? The response to this question is related to freight traffic growth and competitiveness.

Globalization has resulted in a spectacular increase in international transactions and freight. It has also required increases in the capacity and speed of the movement of goods, accompanied by a need for lower unit costs of transport.

Most international trade in goods is by sea, especially in transoceanic trade. The responses were not long in coming. There has been a steady increase in the international merchant fleet, both in terms of the number and the size of vessels. This increased load capacity has required a parallel expansion in the ability of ports to facilitate the growing traffic, raising the need for them to innovate. For ports to be competitive, they must be able to move (load, unload & transfer) large quantities of merchandise and do so quickly. In addition, they must be able to incorporate other value adding activities and logistical services. This has led to adaptation through multiple actions. Some of these include:

— The construction of new infrastructure including: Terminals and accesses to them that are larger and deeper and so can accommodate larger vessels. Specialized terminals for the movement of specific goods (containers, vehicles, bulk, etc.) Terminals for connecting the various modes of transport; rail, truck and ships of different size and tonnage (short-sea shipping). The development of LAZ´s (logistics activity zones) with special provisions for all logistical needs including storage areas and facilities such as storage yards, silos, warehouses, workshops, factories, etc. The establishment of dry ports for the grouping of goods.

— The provision of new equipment (cranes of greater tonnage capacity and specialization, conveyors, ramps, platforms, vehicles, special facilities for all types of logistical services and value adding activities such as cargo inspection, etc).
— The creation of telematics platforms, which incorporatate ITC´s, to streamline document management, allowing information to flow more quickly and with a lower list of errors. Examples include the transmission of data via EDI and the computerization of management and documentation procedures such as inspection and control, etc.
— The need for certification (prevention, environmental and quality) to show that certain services can be offered with a guarantee.
— Management and organizational change (The introduction of flexible schedules, outsourcing and the involvement of private initiative through administrative concession, etc.).

If countries wish to be competitive, they must have a port system that allows them to be part of international supply chains. In addition, each individual port must be competitive with the other ports operating within their national port system. Therefore, competitiveness and competition must be understood from two perspectives, international and national.

The aim of this paper is twofold. In addition to establishing what are the innovation factors that are perceived to be the most important, those in which there has been an increased effort and the obstacles which they face, we aim to determine an order or establish a ranking between them. The study focuses on the Spanish port system.

METHODOLOGY

In Spain, the port system is state-owned. It comprises of 44 General Interest Ports, managed by 28 Port Authorities, dependent in turn on the Public Authority of State Ports within the Ministry of Development. In addition to external competition, these ports compete against each other, especially those located within the same geographical zones (North coast, Mediterranean, etc.).

This study was based upon the completion of a survey. The questionnaire was developed in two phases. The first phase was comprised of the performance of a national and international literature review of material related to our subject, meetings between members of the research team and representatives of the State Ports and the Port Authority of Santander, and the drafting of the first version of the questionnaire. In the second phase, the content of this first version was shown to industry representatives in order to gain their opinions and suggestions for adapting the questionnaire to the specific reality of the port environment. With the incorporation of these suggestions, the final questionnaire was produced.

The questionnaire was sent out by mail and e-mail to all Spanish Port Authorities (100% of the population). The final number of valid responses received amounted to 25, representing 89.28 percent of the total population studied.

The questionnaire indicated that the research group´s work would focus on analyzing the results associated to questions 1, 6, 10 and 12 through the application of Rasch. These questions are shown in Appendix A.

All questions were based on a Likert type scale, in which subjects were asked to give scores between 1 (no importance) and 5 (extremely important).

The chosen analysis methodology is the Rasch technique. This is because this methodology allows one to work with categorical variables and, among other things, order the factors by level of importance. This makes it the most appropriate methodology for the objective of our work.

The software used for data processing and obtaining the results was Winstep.

RESULTS OF THE ANALYSIS

Analysis of the reliability and validity of measures

The validity, reliability and correlation of the results are presented in Tables 1 and 2, with the 1st table relating to individuals and the second to items. These have been drawn from the information presented in the table of results 3.1. which Winstep refers to as “Summary Statistics”.

Table 1. Reliability and validity of “Individuals”

	INFIT		OUTFIT		RELIABILITY	CORRELATION
	MNSQ	ZSTD	MNSQ	ZSTD		
Question 1	0,95	0	0,98	0,1	0,81	0,99
Question 6	1,02	-0,1	1,01	-0,1	0,74	0,83
Question 10	0,99	-0,2	1,04	-0,1	0,93	0,92
Question 12	1,02	-0,1	1,08	-0,1	0,6	0,52

Table 2. Reliability and validity of “Items”

	INFIT		OUTFIT		RELIABILITY	CORRELATION
	MNSQ	ZSTD	MNSQ	ZSTD		
Question 1	0,99	0	0,98	-0,1	0,79	-0,97
Question 6	0,99	0	1,02	0	0,71	-0,23
Question 10	0,98	-0,1	1,04	0,1	0,8	-0,48
Question 12	0,98	-0,1	1,08	0,3	0,63	-0,9

The overall validity of the measures can be evaluated from the INFIT and OUTFIT indices. As noted, the values obtained are consistent with those required (Linacre, 2009; Oreja, JR 2005, p.40, and Febles, 2008), both for the case of the measures (MNSQ valid in the range (0.5 to 1.5)) as the standard of variances (ZSTD close to 0) and for all questions asked, both to individuals and items.

In terms of reliability, we can see that it is of an acceptable level for questions 1, 6 and 10 (values close to 1), but lower for question 12.

When the information or data is complete, the correlation should be 1 for subjects and -1 for items, (Linacre, 2009). In our application, it is acceptable in the case of the subjects (except question 12) but not in the case of the items.

Furthermore, in the analysis of the results of the Winstep tables, 13: Item and 17: Person, show the existence of anomalous cases (values of infit or outfit greater than 1.20). For several of these, we have found a logical explanation. For the rest, we do not have enough knowledge and information to justify them. In any case, a detailed analysis of each of the subjects and items is beyond the scope of this study.

Results concerning innovation in the port sector

In this section we discuss, for each of the selected questions of the survey, the results that relate to the following Winstep tables: 1 “Variable maps”, 13 “Item: Measure”. They are listed in Tables 4 to 8 of Appendix B.

The commentaries were jointly presented in this section grouped around 3 main blocks. Firstly, the importance of innovation activities. Secondly, the effort to innovate, and finally, the barriers to innovation. All of the concepts relate to the perceptions of the Port Authorities.

Perceived importance of innovation activities

This refers to the results of questions 1 and 6 of the survey, listed in tables 4 to 6 of Appendix B.

All Port Authorities considered innovation to be important, as is demonstrated by the scores. In question 1, the lowest score is 3 and 20% of subjects gave all items the highest score. In question 6, the majority of responses are above 3, with just a single score of 2 and none of 1.

On the maps of the variables, (Table 4) some gaps appear, especially at the extreme sides of the items. In order to improve the questionnaire, more items should be included in order to eliminate these gaps. In this way, the analysis would be more complete and allows us to discriminate between subjects located at these extremes.

All the innovation activities introduced in Question 1 are significant. Ranking them from the highest to lowest importance, the result are: (see tables 4 and 5 of Appendix B): (P1-3) Making changes to the organizational structure, introducing new working procedures, and the facilitation of internal information sharing; (P1-4)

Staff development and business and knowledge management training; (P1-7) Quality of service, customer acquisition and retention; (P1-2) The implementation of new or significantly improved processes; (P1-1) The introduction of services and/or new or significantly improved products; (P1-5) The enhancement of external relationships with the business and academic sectors; and (P1-6) The promotion and marketing strategy of the port.

The items P1-3 and P1-4 appear together, indicating that they explain the same thing. They are, however, distinct concepts, but all of the innovation in item 3 (amendments of the organizational structure, adoption, new working procedures and facilitating the sharing of internal information) is innovation that requires training. Training is accounted for in item 4 (staff development and business and knowledge management training).

There is also an overlap of items 1 (innovation in new services) and 5 (empowerment of external relations). These would be very different categories if we were to think of item 5 in terms of co-operative innovation. It may be that both activities are very important and although they are at the same level, they relate to or explain different things. However, on the other hand, cooperation may come from the part of companies with activities such as the building of new terminals or the addition of new equipment (cranes, etc.). This would enable the offering of new services and therefore overlaps with item 1. In this case, they would reflect the same concept.

In question 6, a more disaggregated analysis has been performed than that in Question 1, allowing us to complete the above (see Appendix A). In this case, the order, from the highest to the lowest level of importance of the innovation activities introduced in Question 6, are (see tables 4 and 6 of the Appendix B): (P6-15) Maintenance (the management of a preventive maintenance plan and a plan for the maintenance of infrastructure); (P6-8) External relations (corporate image, web, community relations with the port and city communities); (P6-13) Contingency plans and security systems for protecting infrastructure and the environment (port operations and services, monitoring and forecasting of environmental effects); (P6-3) Port services (the control of operations, the regulation of services, etc.); (P6-9) Quality (quality systems and certifications, etc.); (P6-4) Sales and marketing (Searching for new traffic, relationships with clients, carrying out studies, etc.); (P6-1) Strategic planning (business plan development, annual reports, planning for the use of port areas, objective monitoring, etc.); (P6-7) Legal services and administrative management (e-administration); (P6-10) Environmental Issues (environmental impact, sustainability, waste management, certifications, etc.); (P6-6) Finance and economics (economic management, coordination and budgeting, internal financial control, etc.); (P6-12) Plans and Protection systems (ships and port facilities); (P6-16) Promotion and Sponsorship of scientific and technological R & D within the port (Agreements with universities or research centers, research grants and doctoral programs and the development of patents, etc.); (P6-11) Information systems, communication and control systems (IT, telematics, cameras and sensors, etc.); (P6-2) Human resources (selection, training, internal promotion, labor relations, etc.); (P6-5) Sales and marketing (Searching for new traffic, relationships with clients, carrying out studies, etc.); (P6-14) Projects and construction (the design and development of new infrastructure and port facilities).

Here we can see three overlaps, but we understand that in no case is this a result of the incorporation of the same information when dealing with very different concepts.

Perception of the effort to innovative

In question 10 (see Appendix A) the Port Authorities were asked what, according to their point of view, was the level of effort to innovate in each of the activities or areas raised in the question.

The result show, in descending order, that the activities in which there is most effort to innovate are (see tables 4 and 7):

Strategic planning (business plan development, annual reports, planning for the use of port areas, objective monitoring, etc.) (P10-1); Contingency plans and security systems for protecting infrastructure and the environment (port operations and services, monitoring and forecasting of environmental effects) (P10-13); Information systems, communication and control systems (IT, telematics, cameras and sensors, etc.) (P10-11); Plans and Protection systems (ships and port facilities) (P10-12); Projects and construction (the design and development of new infrastructure and port facilities) (P10-14); Port services (the control of operations, the regulation of services, etc.) (P10-3); Maintenance (the management of a preventive maintenance plan and a plan for the maintenance of infrastructure) (P10-15); Environmental Issues (environmental impact, sustainability, waste management, certifications, etc.) (P10-10); Quality (quality systems and certifications, etc.) (P10-9); Promotion and Sponsorship of scientific and technological R & D within the port (Agreements with universities or research centers, research grants and doctoral programs and the development of patents, etc.) (P10-16); Human resources (selection, training, internal promotion, labor relations, etc.) (P10-2); Sales and marketing (Searching for new traffic, relationships with clients, carrying out studies, etc.) (P10-5); The management of concessions and authorizations (P10-4); External relations (corporate image, web, community relations with the port and city communities) (P10-8); Finance and economics (economic management, coordination and budgeting, internal financial control, etc.) (P10-6); and Legal services and administrative management (e-administration) (P10-7).

A more detailed analysis of the map of variables (see Table 4, Appendix B) allows us to identify, as previously discussed in questions 1 and 6, two gaps at the extreme sides of the items (above and below the T). This coincidence is not surprising since the items in question 10 coincide completely with those of Question 6. In order to improve the questionnaire, more items should be included in order to eliminate these gaps. In this way, the analysis would be more complete and allows us to discriminate between subjects located at these extremes.

There are also several overlapping items. In some cases we believe it may be that some concepts are included in more than one item (eg P10.13 in P10.1). In other cases, the concepts are different, but are within the same line of work, as is the case with the P10.9 and P10.10 items, that are each considered to be a component part of the "integrated management systems (prevention, environment and quality)". In the remaining cases, the concepts are distinct from one another, but carry an equal level of importance.

If we compare the importance given to different innovative activities and the effort devoted to them, we see that there is a clear distance or difference between them (see Table 4, Appendix B). Specifically, the effort to innovative is smaller than the importance attached to it. We therefore need to ask, "What are the factors causing this shortfall in the effort to innovate"? This is addressed in the following paragraph which looks at various obstacles to innovation.

Perceived barriers to innovation

In order to explain what are the obstacles to greater innovative effort by the Port Authority, question 12 was included in the survey (see Appendix A).

The results (see Table 8, Appendix B) show that, according to the perception of the subjects, the obstacles facing innovation, in descending order of importance are: Inadequate staffing for the activity (P12-3); A poor innovation culture (P12-5) Difficulties in finding cooperation partners for innovation (P12-6); A lack of information about technology (This stems from an insufficient observation of technology developments) (P12-4); limited financial resources (P12-1) A lack of demand for innovations (P12-7), and insufficient information about programs and guidance for accessing external finance (P12-2).

CONCLUSIONS

The main conclusions drawn from this study, in addition to the rankings established in the previous paragraphs, are as follows:

1) Innovation is perceived to be highly important within the Spanish port system and particularly by the Port Authorities. Innovation in ports has many facets, both organizational, technological and commercial and are all perceived to be relevant.
2) Although an effort to innovate by Port Authorities exists, it appears to be insufficient when compared with the importance placed upon it.

3) The principal obstacles to innovation in ports are both internal and external, being perceived as the inadequate allocation of scarce resources and the lack of a culture of innovation.
4) All of the factors we have discussed are relevant, but the Rasch technique has detected that they are insufficient to discriminate between the behavior of all ports. Therefore, in order to improve aspects of this work, the Rasch methodology would suggest the need for further future research.

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APPENDIX A: Questions and associated items

Question 1
In the specific field of port activities, and according to your point of view, give a score between 1 (no importance) and 5 (extremely important) to the following activities to reflect the level of importance assigned to them by the Port Authority:

- P1-1 The introduction of services and/or new or significantly improved products.
- P1-2 The implementation of new or significantly improved processes.
- P1-3 Making changes to the organizational structure, introducing new working procedures, and the facilitation of internal information sharing.
- P1-4 Staff development and business and knowledge management training.
- P1-5 The enhancement of external relationships with the business and academic sectors.
- P1-6 The promotion and marketing strategy of the port.
- P1-7 Quality of service, customer acquisition and retention.

Question 6
According to your point of view, give a score between 1 (no importance) and 5 (extremely important) for the importance of the following innovative activities in achieving the proper functioning of the responsibilities assigned to the Port Authority in the following areas: (see the table of items for Questions 6 and 10).

Question 10
According to your point of view, and with reference to the last five years (2004-08), give a score between 1 (no effort) and 5 (extremely high level of effort) for the degree of effort to innovate that has developed within the Port Authority in the following areas: (see table of items for questions 6 and 10).

Question 12
According to your point of view, and with reference to the last five years (2004-08), give a score between 1 (no importance) and 5 (extremely important) for the degree of importance that the following factors have played in hindering innovative activities or influencing the Port Authority in the decision not to innovate:

- P12-1 limited financial resources.
- P12-2 Insufficient information about programs and guidance for accessing external finance.
- P12-3 Inadequate staffing.
- P12-4 A lack of information about technology (Insufficient observation of technological developments).
- P12-5 A poor innovation culture.
- P12-6 Difficulties in finding cooperation partners for innovation.
- P12-7 Lack of demand for innovations.

Table 3. Items for questions 6 and 10

1	Strategic planning (business plan development, annual reports, planning for the use of port areas, objective monitoring, etc.).
2	Human resources (selection, training, internal promotion, labor relations, etc.).
3	Port services (the control of operations, the regulation of services, etc.).
4	The management of concessions and authorizations.
5	Sales and marketing (Searching for new traffic, relationships with clients, carrying out studies, etc.).
6	Finance and economics (economic management, coordination and budgeting, internal financial control, etc.).
7	Legal services and administrative management (e-administration).
8	External relations (corporate image, web, community relations with the port and city communities).
9	Quality (quality systems and certifications, etc.).
10	Environmental Issues (environmental impact, sustainability, waste management, certifications, etc.).
11	Information systems, communication and control systems (IT, telematics, cameras and sensors, etc.).
12	Plans and Protection systems (ships and port facilities).
13	Contingency plans and security systems for protecting infrastructure and the environment (port operations and services, monitoring and forecasting of environmental effects).
14	Projects and construction (the design and development of new infrastructure and port facilities).
15	Maintenance (the management of a preventive maintenance plan and a plan for the maintenance of infrastructure).
16	Promotion and Sponsorship of scientific and technological R & D within the port (Agreements with universities or research centers, research grants and doctoral programs and the development of patents, etc.).

APPENDIX B Tables of Results

Table 4. Variable Maps

Question 1
importance of general innovative activities

```
PERSONS - MAP - ITEMS
       <more>|<rare>
  4   XXXXX  +
             |
          X  |
             |
             |
             |
  3          +
          X  |
             |
            S|
             |
      XXXXX  |
  2          +T
             |
             |  P1-6
         XX  |
             |
             |
  1          +S
             |
         XX M|  P1-1   P1-5
             |
             |
        XXX  |
  0          +M P1-2
             |
             |
             |
             |
          X  |  P1-7
 -1          +S
            S|  P1-3   P1-4
             |
        XXX  |
             |
             |
 -2          +T
             |
             |
             |
             |
 -3         T+
             |
             |
             |
             |
             |
 -4       X  +
             |
             |
             |
             |
             |
 -5       X  +
       <less>|<frequ>
```

Question 6
Importante of specific innovative activities

```
PERSONS - MAP - ITEMS
        <more>|<rare>
  3        X  +
              |
              |
              |
              |
              |
              |
              |
              |
              |
  2        X  +
              |
             T|
              |
           X  |
              |
           X  |
              |T P6-14
          XX  |
           X  |
  1          S+
              |
              |  P6-5
              |  P6-2
           X  |S
           X  |
              |  P6-11
          XX M|  P6-12   P6-16
          XX  |
              |  P6-10   P6-6
  0       XX  +M P6-7
       XXXXX  |
              |  P6-1
           X  |  P6-4    P6-9
              |
           X S|
              |S P6-3
           X  |  P6-13
              |  P6-8
           X  |
 -1           +
           X  |
              |  P6-15
             T|T
              |
              |
              |
              |
              |
              |
 -2           +
        <less>|<frequ>
```

Question 10
Effort in innovation

```
PERSONS - MAP - ITEMS
      <more>|<rare>
 3         T+
            |
            |
            |
            |
         X  |
            |
 2          +
         X  |
        XX  |
         X S|
         X  |  P10-7
            |T
            |  P10-6
 1       X  +
        XX  |
        XX  |S P10-8
            |
         X  |
        XX  |  P10-2   P10-4   P10-5
        XX M|  P10-16
 0       X  +M
         X  |  P10-10  P10-9
         X  |  P10-15
            |
         X  |  P10-11  P10-12  P10-14  P10-3
            |S P10-1   P10-13
            |
-1       X  +
            |
           S|T
            |
         X  |
            |
         X  |
-2          +
            |
            |
         X  |
           T|
            |
            |
-3          +
            |
            |
            |
            |
         X  |
            |
-4          +
      <less>|<frequ>
```

Table 5. "Item: Measure" for question 1.

ENTRY NUM	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT OBS%	MATCH EXP%	ITEM	G
6	98	25	1.68	.44	1.09	.4	.99	.2	.79	.80	63.2	66.2	P1-6	0
1	102	25	.75	.44	.64	-1.3	.61	-1.1	.85	.78	63.2	62.8	P1-1	0
5	104	25	.75	.44	.87	-.4	.81	-.4	.82	.80	63.2	62.8	P1-5	0
2	108	25	-.07	.46	.83	-.5	.76	-.7	.82	.79	89.5	65.8	P1-2	0
7	112	25	-.80	.46	1.27	.8	1.59	.9	.63	.69	63.2	69.8	P1-7	0
3	111	25	-1.16	.52	1.17	.6	1.13	.5	.74	.78	73.7	73.3	P1-3	0
4	111	25	-1.16	.52	1.07	.3	.95	.0	.78	.78	63.2	73.3	P1-4	0
MEAN	106.6	25.0	.00	.47	.99	.0	.98	-.1			68.4	67.7		
S.D.	5.0	.0	1.02	.03	.20	.7	.29	.6			9.3	4.2		

Table 6. "Item: Measure" for question 6.

ENTRY NUM	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT OBS%	MATCH EXP%	ITEM	G
14	92	25	1.31	0.36	1.08	0.4	1.09	0.4	0.5	0.55	54.2	57.3	P6-14	0
5	94	25	0.83	0.3	1.02	0.2	1.21	0.8	0.51	0.53	50	49.9	P6-5	0
2	84	25	0.72	0.26	1.09	0.5	1.08	0.4	0.54	0.57	29.2	42	P6-2	0
11	112	25	0.44	0.44	0.74	-1.9	0.71	-1.8	0.55	0.37	79.2	65.6	P6-11	0
16	97	24	0.28	0.3	1.34	1.4	1.47	1.8	0.32	0.47	43.5	48.3	P6-16	0
12	101	25	0.27	0.38	0.75	-0.9	0.74	-0.9	0.63	0.48	66.7	66.6	P6-12	0
10	102	25	0.15	0.33	1.02	0.2	1.02	0.2	0.46	0.46	62.5	56.2	P6-10	0
6	89	25	0.05	0.32	0.82	-0.6	0.81	-0.6	0.65	0.56	58.3	57.6	P6-6	0
7	91	25	0.01	0.32	0.78	-0.8	0.79	-0.7	0.65	0.54	75	55.1	P6-7	0
1	95	25	-0.21	0.26	1.39	1.5	1.39	1.4	0.36	0.51	41.7	44.2	P6-1	0
9	98	25	-0.25	0.34	1.42	1.2	1.48	1.3	0.26	0.48	58.3	64.5	P6-9	0
4	94	25	-0.28	0.29	0.85	-0.5	0.85	-0.5	0.59	0.52	45.8	48.5	P6-4	0
3	108	25	-0.63	0.36	0.71	-1.2	0.7	-1.2	0.58	0.41	70.8	62.2	P6-3	0
13	103	25	-0.67	0.28	0.96	-0.1	1	0.1	0.43	0.44	33.3	52.6	P6-13	0
8	107	25	-0.82	0.42	0.93	-0.2	0.91	-0.2	0.48	0.43	70.8	69.3	P6-8	0
15	88	25	-1.19	0.38	1	0.1	1.01	0.1	0.36	0.37	62.5	60.7	P6-15	0
MEAN	97.2	24.9	0	0.34	0.99	0	1.02	0			56.4	56.3		
S.D.	7.6	0.2	0.63	0.05	0.22	0.9	0.25	1			14.3	8		

Table 7. "Item: Measure" for question 10.

ENTRY NUM	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT OBS%	MATCH EXP%	ITEM	G
7	73	25	1.49	.29	.80	-.7	.81	-.4	.65	.60	52.0	54.1	P10-7	0
6	76	25	1.19	.33	1.30	1.0	1.32	1.0	.47	.60	56.0	60.7	P10-6	0
8	85	25	.68	.30	.90	-.3	1.61	1.5	.67	.68	60.0	57.4	P10-8	0
4	73	25	.35	.27	.90	-.3	.90	-.3	.74	.69	60.0	50.4	P10-4	0
5	75	25	.27	.29	.63	-1.4	.63	-1.4	.83	.70	60.0	53.4	P10-5	0
2	71	25	.24	.27	1.02	.2	1.03	.2	.68	.67	52.0	51.1	P10-2	0
16	61	25	.16	.33	.85	-.5	.82	-.6	.69	.60	56.0	59.1	P10-16	0
9	81	25	-.11	.28	1.69	2.1	2.01	2.8	.47	.73	36.0	52.3	P10-9	0
10	92	25	-.20	.28	1.12	.6	1.19	.8	.62	.68	36.0	49.4	P10-10	0
15	64	25	-.25	.35	.84	-.5	.87	-.4	.66	.58	60.0	60.9	P10-15	0
3	85	25	-.54	.26	.99	.1	1.02	.2	.71	.72	40.0	48.9	P10-3	0
14	83	25	-.56	.27	.78	-.8	.77	-.8	.79	.70	52.0	46.5	P10-14	0
12	86	25	-.59	.31	.98	.0	1.00	.1	.69	.70	60.0	56.4	P10-12	0
11	97	25	-.62	.32	.70	-1.1	.74	-1.0	.79	.69	60.0	57.2	P10-11	0
13	87	25	-.76	.27	1.30	1.1	1.30	1.1	.60	.71	40.0	45.9	P10-13	0
1	87	25	-.77	.24	.79	-.7	.67	-1.1	.79	.72	52.0	48.0	P10-1	0
MEAN	79.8	25.0	.00	.29	.98	-.1	1.04	.1			52.0	53.2		
S.D.	9.6	.0	.66	.03	.26	.9	.36	1.1			8.7	4.8		

Table 8. "Item: Measure" for question 12.

ENTRY NUM	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT OBS%	MATCH EXP%	ITEM	G
2	74	25	0.39	0.2	0.8	-0.8	0.78	-0.8	0.64	0.49	48	36.9	P12-2	0
7	75	25	0.27	0.21	0.94	-0.1	0.93	-0.2	0.54	0.48	56	36.9	P12-7	0
1	79	25	0.22	0.17	0.75	-1	0.75	-0.9	0.67	0.56	28	27.8	P12-1	0
4	82	25	0.14	0.2	0.9	-0.3	0.87	-0.4	0.58	0.52	40	43.5	P12-4	0
6	77	25	-0.11	0.2	0.97	0	1.58	2	0.35	0.47	48	36.7	P12-6	0
5	88	25	-0.32	0.2	1.22	0.9	1.18	0.8	0.37	0.51	32	34.2	P12-5	0
3	99	25	-0.58	0.2	1.28	1	1.45	1.3	0.38	0.54	36	38.9	P12-3	0
MEAN	82	25	0	0.2	0.98	-0.1	1.08	0.3			41.1	36.4		
S.D.	8.2	0	0.33	0.01	0.18	0.7	0.31	1			9.2	4.4		

INNOVACIÓN EN EL SECTOR PORTUARIO ESPAÑOL

RESUMEN

La globalización ha generado un incremento espectacular del tráfico de mercancías a nivel mundial y en particular del transporte marítimo. En respuesta a las mayores necesidades de capacidad de carga se ha producido un constante incremento de la flota mercante mundial y también, de forma paralela, aparecen nuevos requerimientos para los puertos, surgiendo la necesidad de innovar.

Los países, si quieren ser competitivos, necesitan un sistema portuario que les permita formar parte de las cadenas logísticas internacionales. Además, cada puerto de forma individual, ha de ser competitivo respecto del resto de puertos del mismo sistema portuario. Por tanto, la competitividad y la competencia han de entenderse desde una doble perspectiva, internacional y nacional.

El trabajo analiza la percepción de las Autoridades Portuarias españolas sobre la innovación en el sistema portuario nacional. El objetivo es conocer las actividades de innovación que se perciben como más importantes, aquéllas en las que se ha efectuado un mayor esfuerzo y los obstáculos a la innovación, aplicando la metodología Rasch.

METODOLOGÍA

En España, el sistema portuario es de titularidad estatal. Está integrado por 44 Puertos de Interés General, gestionados por 28 Autoridades Portuarias, dependientes a su vez del Organismo Público Puertos del Estado, del Ministerio de Fomento. Además de la competencia exterior, estos puertos compiten entre si, especialmente con los de la misma fachada (Norte, Mediterráneo, etc.).

El estudio ha exigido como paso previo la realización de una encuesta.

El cuestionario se desarrolló en dos fases. En la primera se hizo una revisión de la literatura, nacional e internacional, sobre el tema objeto de estudio; reuniones del equipo investigador con representantes de Puertos del Estado y la Autoridad Portuaria de Santander; y elaboración de la primera versión del cuestionario. En la segunda fase se realizó un pretest de contenido entre representantes del sector a fin de recoger opiniones o sugerencias para adaptar el cuestionario a la realidad específica del ámbito portuario; incorporación de las mismas y obtención del cuestionario final.

El envío del cuestionario se ha realizado por correo postal y/o electrónico al conjunto de Autoridades Portuarias Españolas (100% de la población). El número de contestaciones válidas finalmente recibidas ascendió a 25, lo que representa el 89,28 por ciento de la población objeto de estudio.

Del indicado cuestionario, el presente trabajo se centra en el análisis de los resultados asociados a la aplicación del Rasch a las preguntas 1, 6, 10 y 12 que aparecen reproducidas en el anexo I.

Todas ellas tienen una escala tipo likert, con puntuaciones entre 1 y 5, donde 1 significa nada y 5 mucho.

La metodología de análisis elegida es la técnica Rasch, porque esta herramienta permite trabajar con variables categóricas y, entre otras cosas, ordenar los factores por grado de importancia. Y por lo tanto, consideramos que es una metodología especialmente apropiada para el objetivo de nuestro trabajo.

La aplicación informática utilizada para el tratamiento de los datos y la obtención de los resultados ha sido el Winstep.

CONCLUSIONES

Las principales conclusiones que se derivan del estudio realizado, además de los rankings que se han dejado establecidos en los correspondientes apartados, son las siguientes:

1) La innovación se percibe como muy importante desde el sistema portuario español y en particular por las Autoridades Portuarias. La innovación en puertos tiene múltiples aspectos, tanto organizativos como tecnológicos y comerciales, todos ellos relevantes.
2) El esfuerzo innovador de las Autoridades Portuarias, aun existiendo, parece insuficiente si lo comparamos con la importancia asignada a las actividades de innovación.
3) Los principales obstáculos a la innovación en puertos vienen tanto del ámbito interno como externo, especialmente insuficiente dotación de recursos y escasa cultura innovadora.
4) Los factores analizados son todos ellos relevantes, pero la técnica Rasch ha permitido detectar que son insuficientes para poder discriminar los comportamientos de todos los puertos. En este sentido la metodología Rasch, al establecer aspectos a mejorar, orienta la investigación futura.

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