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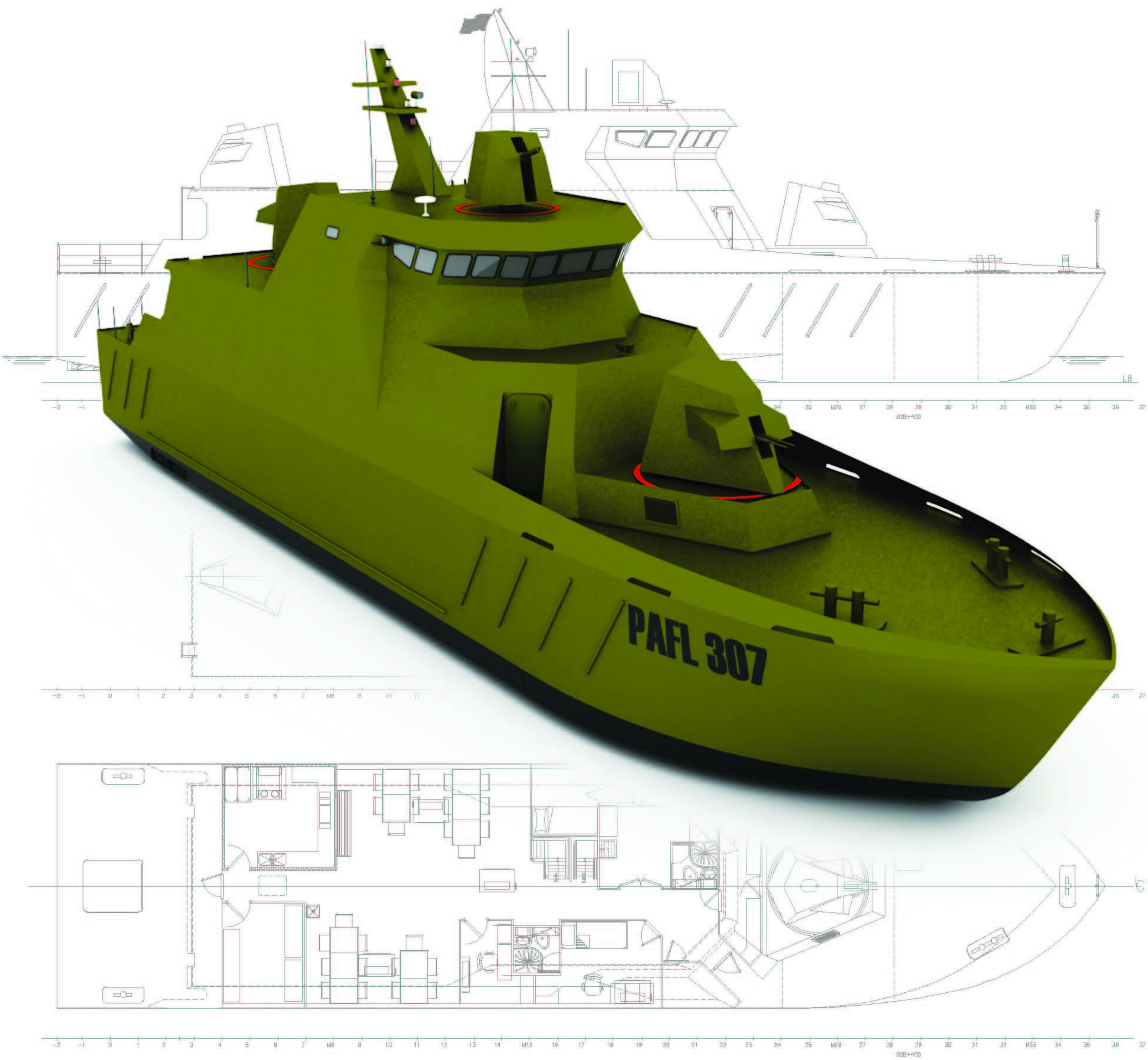

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Ship Science & Technology is a specialized journal in topics related to naval architecture, and naval, marine and ocean engineering. Every six months, the journal publishes scientific papers that constitute an original contribution in the development of the mentioned areas, resulting from research projects of the Science and Technology Corporation for the Naval, Maritime and Riverine Industries, and other institutions and researchers. It is distributed nationally and internationally by exchange or subscription.

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COLOMBIA

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Editorial Note

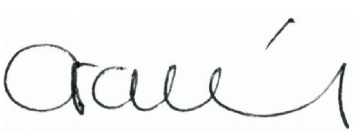
Cartagena de Indias, 21 January 2012.

During 2011, the Science and Technology Corporation for the Development of the Naval, Maritime, and Riverine Industries –COTECMAR led the construction of the Value Propositionthat allowed the inclusionof the shipyard industryamong the world-class sectors to be promoted by the Ministry of Commerce, Industry, and Tourism, through the Productive Transformation Program. Likewise, in association with the "Almirante Padilla" Naval Academy, *Universidad Tecnológica de Bolívar*, *Universidad del Norte*, and the Cartagena Chamber of Commerce, the Naval Engineering and Design macro-project,to be funded through resources from the Science and Technology Fund of the General Royalty System,was generated.The objective of the program is to "enhance the innovation capacities of the Naval Construction and Design sector of the Colombian Caribbean region by developing specific projects associated to high-impact products, technological services, and acceleration of technology-based companies", which will propitiate improved competitiveness of the national shipyard sector.

Other sectoral initiatives being currently developed by COTECMAR and which seek to improve the competitiveness of the shipyard industry include projects like the "Enhancement of the Shipyard Industry Supply Chain", executed with resources from the BANCOLDEX, INNPULSA program, and the "Shipyard Industry Sectoral Innovation System", developed jointly with two of our partner universities (*Universidad del Norte* and *Universidad Tecnológica de Bolívar*).

The formulation and implementation of strategies like those already mentioned have earned COTECMARrecognition from COLCIENCIAS as a Center for Sectoral Technological Development.

This issue of Ship Science and Technology (*Ciencia y Tecnología de Buques*) is dedicated to competitiveness in the shipyard industry. To introduce the scientific articles included in this issue, I have invited a friend of COTECMAR: Thomas Lamb, professional and professor with vast international recognition. I hope you enjoy this special issue of Ship Science and Technology.



Commander, OSCAR DARÍO TASCÓN MUÑOZ

"Letter from the invited editor, special issue on Competitiveness in the Marine Industry"

Seattle, WA, U.S.A., 21 January 2012.

This is 2012 and the world still struggles with the economic downturn. This affects trade, shipping, and ultimately shipbuilding. The three major shipbuilding countries, China, Korea, and Japan are all struggling with almost zero orders for new ships.

In Colombia, the shipbuilding industry has been showing a stable behavior in the last decade, mainly fueled by domestic needs and through the entrance into new market niches internationally. Nevertheless, the country still faces great challenges in competitiveness, particularly in critical dimensions as regulatory framework, business environment, technological infrastructure and productivity.

Despite this fact, there are organizations in the country like COTECMAR, which is responsible for developing the shipbuilding and ship repair industry. This Organization is unique, in that it is a non-profit organization operating for the benefit of all Colombian shipyards and the maritime industry in general. Any revenue is funneled back into the maritime business through its Technological Development & Innovation Plan.

As part of that Plan, COTECMAR quickly recognized the need for education in the professional fields of ship design and shipbuilding. COTECMAR has been working with important Colombian universities to develop programs to support industry needs. As part of these initiatives, the Ship Science & Technology Journal was introduced to invite authors from all over the world to contribute their knowledge and, thus, ensure that Colombian maritime professionals would be at the forefront of maritime technology. Its success (this is the tenth Regular edition and the second Special edition) is clear by the quality of the papers and the international demand for copies.

Of the papers in this issue, two reflect how the environment is now an important part in the development of any industrial undertaking, especially shipbuilding and in the offshore industry, two focus on performance benchmarking, the remaining three on shipping costs and prediction of near future performance, offshore transfer of containers to smaller ships and/or barges where port facilities are not available, and the final one on optimizing shipyard warehouse layout.

The range of topics reflects that shipbuilding cannot be developed alone; it is part of the overall maritime industry, which must be developed on a wide front and in parallel.

The Editorial Board welcomes suggestions for future contributions and suggestions on how to improve the Journal with the objective of meeting its goal to become an effective tool in the education of Colombian Shipbuilders.

Thomas Lamb
Emeritus Research Scientist and Adjunct Professor
Naval Architecture & Marine Engineering Department - University of Michigan

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Nota Editorial

Cartagena de Indias, 21 de Enero de 2012.

Durante el 2011, COTECMAR lideró la construcción de la Propuesta de Valor que permitió que el sector astillero fuera incluido dentro de los sectores de clase mundial a ser incentivados por el Ministerio de Comercio, Industria y Turismo, a través del Programa de Transformación Productiva. De igual forma, en asocio con la Escuela Naval "Almirante Padilla", la Universidad Tecnológica de Bolívar, la Universidad del Norte, y la Cámara de Comercio de Cartagena, se generó el macroproyecto de Diseño e Ingeniería Naval para ser financiado con recursos del Fondo de Ciencia y Tecnología del Sistema General deRegalías y que tiene como objetivo "Fortalecerlas capacidades de innovación del sector de Diseño y Construcción Naval de la Región Caribe Colombiana mediante el desarrollo de proyectos específicos asociados a productos de alto impacto, servicios tecnológicos y de aceleración de empresas de base tecnológica",el cual propiciará el mejoramiento de la competitividad del sector astillero nacional.

Otras iniciativas de carácter sectorial que ha venido desarrollando COTECMAR a la fecha y que tienen como objetivo el mejoramiento de la competitividad de la industria astillera incluyen proyectos tales como el de "Fortalecimiento de la Cadena de Proveedores de la Industria Astillera", ejecutado con recursos del programa INNPULSA de Bancoldex, y el "Sistema Sectorial de Innovación de la Industria Astillera",desarrollado en conjunto con dos de nuestras universidades socias (Universidad del Norte y Universidad Tecnológica de Bolívar).

La formulación e implementación de estrategias como las mencionadas anteriormente, le han valido a la Corporación de Ciencia y Tecnología para el Desarrollo de la Industria Naval, Marítima y Fluvial – COTECMAR, el reconocimiento por partede COLCIENCIAS como Centro de Desarrollo Tecnológico Sectorial.

Esta edición de Ciencia y Tecnología de Buques está dedicada a la competitividad de la industria astillera. Para introducir los artículos científicos incluidos en la misma, he invitado a un amigo de COTECMAR: Thomas Lamb, profesional y catedrático con amplio reconocimiento internacional. Espero que disfruten de esta edición especial de Ciencia y Tecnología de Buques.

Capitán de Fragata OSCAR DARÍO TASCÓN MUÑOZ

"Carta del editor invitado, número especial sobre la Competitividad en la Industria Naval"

Seattle, WA, U.S.A., 21 de Enero de 2012.

Estamos en el año 2012 y el mundo aún está luchando con la recesión económica, situación que afecta el comercio, el transporte marítimo y, por consiguiente, la industria de construcción naval. Los tres países más grandes en la construcción naval, China, Corea y Japón, se están enfrentando a una disminución en el número de pedidos para nuevas embarcaciones.

En Colombia, la industria de la construcción naval ha presentado en la última década una dinámica estable, impulsada principalmente por el crecimiento de la demanda del mercado interno y la reciente incursión en nuevos nichos de mercado a nivel internacional. Aun así, el país aún enfrenta grandes retos en materia competitiva, específicamente en dimensiones críticas como el marco normativo, el ambiente para negocios, la infraestructura tecnológica y la productividad.

Sin embargo, en Colombia existen organizaciones como COTECMAR, la cual tiene la responsabilidad de desarrollar la industria de construcción y reparación de embarcaciones. Ésta organización es única en la industria, al no tener ánimo de lucro y operar para el bien de todos los astilleros colombianos y demás actores de la cadena productiva. Cualquier excedente financiero producido se reinvierte de acuerdo a un Plan de Desarrollo Tecnológico e Innovación.

En el marco de su gestión, COTECMAR ha identificado la necesidad de la educación en los campos del diseño y la construcción naval. La Organización ha estado trabajando de la mano con reconocidas universidades colombianas para desarrollar programas ajustados a las necesidades del entorno productivo. Iniciativas como la Revista Ciencia y Tecnología de Buques (Ship Science & Technology Journal) se presentaron como una manera de invitar a autores de todo el mundo a contribuir con su conocimiento y así, asegurar que los profesionales colombianos estén a la vanguardia de la tecnología marítima. Su éxito (esta es la Décima Edición Regular y la Segunda Edición Especial) queda claro debido a la calidad de los artículos y a la demanda internacional para sus ejemplares.

De los artículos en esta entrega, dos (2) reflejan cómo el medio ambiente es ahora parte importante del desarrollo de cualquier empresa industrial, especialmente en la construcción de embarcaciones y en la industria de exploración costa afuera, dos (2) se enfocan en la evaluación comparativa del rendimiento, otros tres (3) en los costos del transporte marítimo y en la predicción del rendimiento en el futuro cercano, transferencia en alta mar de contenedores a embarcaciones más pequeñas y/o barcazas donde no hay instalaciones portuarias disponibles; el artículo final se enfoca en la optimización de la distribución física de los almacenes de un astillero. El rango de los temas refleja que la construcción naval no se puede desarrollar sola; es parte de la industria marítima en general, que se debe desarrollar en un frente amplio y en paralelo.

El Consejo Editorial agradece las sugerencias para contribuciones futuras y sugerencias en cómo mejorar la Revista con el propósito de cumplir con su meta de convertirse en una herramienta efectiva para la transferencia de conocimiento hacia la industria astillera colombiana.

Thomas Lamb
Investigador Científico Emérito y Profesor Adjunto
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Research in offshore transfer cargo operations; challenges, developments, and new frontiers

Investigaciones en las operaciones de transferencia de carga offshore, desafíos, desarrollos y nuevas fronteras.

Max Suell Dutra [1]
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Katrin Ellermann [3]
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Abstract

Currently, offshore operations are considered activities with high impact on the economy, which stands in direct relation to the products of great importance and value for diverse economic sectors. Thus, it becomes necessary to implement new technologies that make the manipulation of these products faster and easier. In this work, the authors introduce the problem in offshore cargo transfer operations. This problem involves different kinds of areas: logistics, dynamics, and control are some of them. The authors present an approach for the last two. In the dynamic problem is presented a study on the dynamics of a suspended load connected to a crane via a mechanism with two prismatic degrees of freedom. The studies show the complex large-amplitude motion of the load given the visibly nonlinear behavior of the ship. Therefore, the development of a fuzzy controller was necessary to decrease oscillations and position the load in one definitive point of interest. The work presents the test results, demonstrating that this type of manipulator in combination with an effective control strategy allows for the reduction of oscillations in offshore activities.
Key words: Offshore Operations, Nonlinear Control, Load Manipulator, Cargo load transfer.

Resumen

En la actualidad, las operaciones en alta mar se consideran actividades con alto impacto en la economía, lo cual se encuentra en relación directa con los productos de gran importancia y valor para diversos sectores económicos. Así entonces, se hace necesario implementar nuevas tecnologías que permitan más rápida y fácil manipulación de estos productos. En este trabajo, los autores presentan el problema en operaciones de transferencia de carga en alta mar. Este problema involucra diferentes tipos de áreas: logística, dinámica y control, son algunos de ellos. Los autores presentan un acercamiento para las últimas dos. En el problema de dinámica se presenta un estudio sobre la dinámica de una carga suspendida conectada a una grúa mediante un mecanismo con dos grados prismáticos de libertad. Los estudios demuestran el movimiento complejo de gran amplitud de la carga dada el comportamiento visiblemente no-lineal de la embarcación. Entonces, el desarrollo de un controlador de lógica difusa fue necesario para disminuir las oscilaciones y posicionar la carga en un punto de interés definitivo. El trabajo presenta los resultados de pruebas, demostrando que este tipo de manipulador en combinación con una estrategia efectiva de control permite la reducción de oscilaciones en actividades en alta mar.
Palabras claves: Operaciones offshore, Control no lineal, Manipulador de carga, Transferencia de carga.

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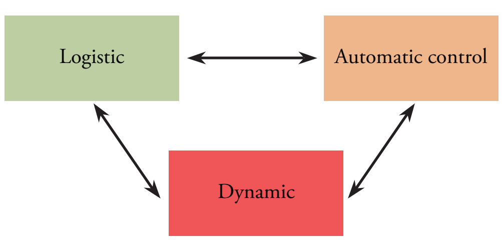
Introduction

Container ships account for most of the intercontinental load transports. This is the reason for the interest in the development of innovative alternatives that help to load and off-load cargo to and from ships. Offshore load operations are part of this new way of working with cargo; for this reason, a diverse number of research projects and developments in innovative alternatives that support this kind of operation to work in a variety of situations are helping to establish a new way of performing load operations (*Nottebom T, 2004; Diesel M, 2005*).

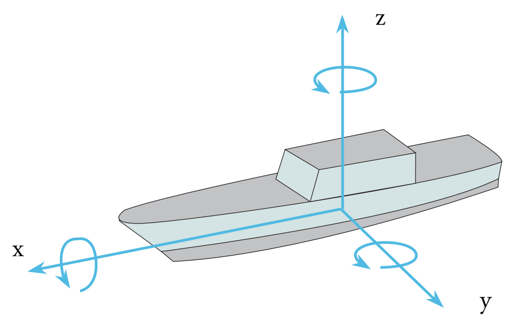
All the works with offshore cargo transfer operations can be divided into three different types of areas. The first is a logistics problem; this problem involving all the procedures and norms of the process is basically "how to" and "where, when" concerns. The second is dynamic and studies specifically the dynamic problem between the two ships. Finally, the control problem is necessary to work efficiently in different kinds of sea levels, wind speeds, and operator experience. To summarize, Fig. 1 presents the principal areas involved in offshore transfer cargo operations.

Fig 1. Offshore Transfer cargo operation areas



This paper presents a study on the dynamics of a suspended load that is coupled with a mechanism of two prismatic Degrees of Freedom (DoF). Because of the nonlinear behavior of the ship, it is possible to see complex load dynamics that, emphasizing the need to use a control mechanism that allows for the reduction of oscillations and positioning the load on a particular point of interest. In order to carry out this task, a fuzzy logic controller was implemented. The degrees of freedom of a ship are presented in Fig. 2.

Fig 2. Degrees of freedom



Cargo Manipulationr

A Cartesian model for the cargo manipulator was developed, which is positioned on the ship. The first step is to determine the motion of the ship in all degrees of freedom. Generally, to identify or model the movement of the ship, six degrees of freedom are used (*Fossen T, 1994; Sphaier HS 2005*). For that reason, the final position of the ship is given by the combination of six movements (three rotations: roll, pitch and yaw; and three translations: surge, sway, and heave).

Having defined the movements of the ship, the kinematics is calculated for each degree of freedom in specific order. For this particular case, the first movements will be the rotations on each axis, then the displacements. Therefore, it is possible to see the matrix transformation for each axis. The rotation on the X axis in equation (1), rotation on the Y axis in equation (2), and finally, we have a matrix of transformation to the rotation on its axis called Z in equation (3).

$$T_0^1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\theta_{X_N}) & -\sin(\theta_{X_N}) & 0 \\ 0 & \sin(\theta_{X_N}) & \cos(\theta_{X_N}) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$T_1^2 = \begin{bmatrix} \cos(\theta_{Y_N}) & 0 & \sin(\theta_{Y_N}) & 0 \\ 0 & 1 & 0 & 0 \\ -\sin(\theta_{Y_N}) & 0 & \cos(\theta_{Y_N}) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

$$T_2^3 = \begin{bmatrix} \cos(\theta_{Z_N}) & -\sin(\theta_{Z_N}) & 0 & 0 \\ \sin(\theta_{Z_N}) & \cos(\theta_{Z_N}) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

The same procedure is performed for the displacements in the ship's axes, the displacement on axes X, Y, and Z is represented by matrices described in equation (4).

$$T_3^6 = \begin{bmatrix} 1 & 0 & 0 & X_N \\ 0 & 1 & 0 & Y_N \\ 0 & 0 & 1 & Z_N \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

Finally, it is possible to find the actual position of the ship by multiplying the previous matrices, as shown in equation (5).

$$T_0^6 = T_0^1 * T_1^2 * T_2^3 * T_3^6 \quad (5)$$

The result of the multiplication is a matrix transforming the fixed frame to the moving ship frame; this matrix is called T_0^6 and it is denoted as given in equation (6).

$$T_3^6 = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} \end{bmatrix} \quad (6)$$

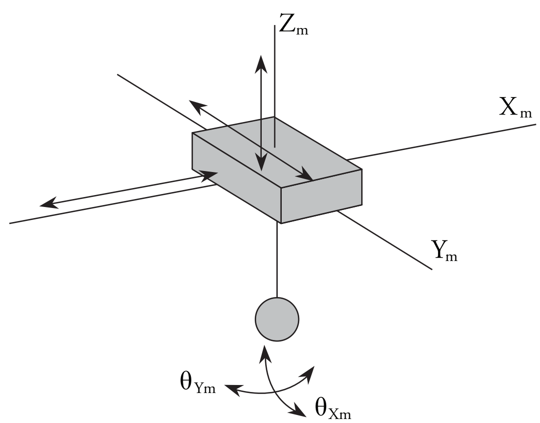
To describe the ship's final position, the elements needed are α_{14}, α_{24} and α_{34}. These components are given in equations (7), (8), and (9).

The elements represent:
X ship position = α_{14}
Y ship position = α_{24}
Z ship position = α_{34}

Manipulator movements

At the time the cargo leaves the ship's surface, it can be considered a hung load, and if all the mass is concentrated on a single point, the system represents itself as a simple pendulum. To improve the dynamic model, the next element to define is the handler. It is defined as a Cartesian handler that moves the hung cargo (simple pendulum). The simplified system cargo manipulator can be seen in Fig. 3.

Fig 3. Cargo manipulator



The position of the pendulum (cargo) in any moment of time relative to the vessel is determined by a set of transformation matrices that start from the ship, passing by the manipulator, and then to the load.

$$\alpha_{14} = -\cos(\theta_{Y_N})\sin(\theta_{Z_N})\,Y_N + \cos(\theta_{Y_N})\cos(\theta_{Z_N})\,X_N + \sin(\theta_{Y_N})\,Z_N \quad (7)$$

$$\begin{aligned}\alpha_{24} = &(-\sin(\theta_{X_N})\sin(\theta_{Y_N})\sin(\theta_{Z_N}) + \cos(\theta_{X_N})\cos(\theta_{Z_N}))\,Y_N + \\ &(\sin(\theta_{X_N})\sin(\theta_{Y_N})\cos(\theta_{Z_N}) + \cos(\theta_{X_N})\sin(\theta_{Z_N}))\,X_N - \sin(\theta_{X_N})\cos(\theta_{Y_N})\,Z_N\end{aligned} \quad (8)$$

$$\begin{aligned}\alpha_{34} = &(\cos(\theta_{X_N})\sin(\theta_{Y_N})\sin(\theta_{Z_N}) + \sin(\theta_{X_N})\cos(\theta_{Z_N}))\,Y_N + \\ &(-\cos(\theta_{X_N})\sin(\theta_{Y_N})\cos(\theta_{Z_N}) + \sin(\theta_{X_N})\sin(\theta_{Z_N}))\,X_N + \cos(\theta_{X_N})\cos(\theta_{Y_N})\,Z_N\end{aligned} \quad (9)$$

$$T_n^m = \begin{bmatrix} 1 & 0 & 0 & X_m \\ 0 & 1 & 0 & Y_m \\ 0 & 0 & 1 & Z_m \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (10)$$

In this case, equation (10) represents the transformation matrix that takes the frame from the ship to the manipulator's frame by taking into account variables , X_m Y_m, which are the axial displacement of the manipulator. Equation (11) is the transformation matrix that changes the manipulator frame to the load frame where L_c is the length of the cable that links the cargo and the manipulator; and θ_{X_m} θ_{Y_m} represent the angles of rotation on the X and Y manipulator's axes which can define the position of cargo at any time.

To define the position of the load with respect to the fixed frame, the transformation matrices of the transformations, T^6_0 T^m_n and T^c_m are multiplied, generating equation (12), which represents the conversion of the fixed frame to the load.

$$T_m^c = \begin{bmatrix} \cos(\theta_{Y_m}) & 0 & \sin(\theta_{Y_m}) & -\sin(\theta_{Y_m}) L_c \\ \sin(\theta_{X_m})\sin(\theta_{Y_m}) & \cos(\theta_{X_m}) & -\sin(\theta_{X_m})\cos(\theta_{Y_m}) & \sin(\theta_{X_m})\cos(\theta_{Y_m}) L_c \\ -\cos(\theta_{X_m})\sin(\theta_{Y_m}) & \sin(\theta_{X_m}) & \cos(\theta_{X_m})\cos(\theta_{Y_m}) & -\cos(\theta_{X_m})\cos(\theta_{Y_m}) L_c \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (11)$$

$$T_m^c = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (12)$$

The result of equation (12) is a 4X4 matrix, for a second time the most important elements of this matrix, which give the position of the load, are written on equation (13) for X, equation (14) for Y and equation (15) for Z.

$$\begin{aligned} \boldsymbol{b_{14}} = {} & \cos(\theta_{Y_N})\cos(\theta_{Z_N})(-\sin(\theta_{Z_N}) L_c + X_m) - \\ & \cos(\theta_{Y_N})\sin(\theta_{Z_N})\ (\sin(\theta_{X_m})\cos(\theta_{Y_m}) L_c + Y_m) + \\ & \sin(\theta_{Y_N})(-\cos(\theta_{X_m})\cos(\theta_{Y_m}) L_c + Z_m) - \cos(\theta_{Y_N})\sin(\theta_{Z_N})\ Y_N + \\ & \cos(\theta_{Y_N})\cos(\theta_{Z_N}) X_N + (\sin(\theta_{Y_N})\ Z_N \end{aligned} \quad (13)$$

$$\begin{aligned} \boldsymbol{b_{24}} = {} & (\sin(\theta_{X_N})\sin(\theta_{Y_N})\cos(\theta_{Z_N}) + \cos(\theta_{X_N})\sin(\theta_{Z_N}))(-\sin(\theta_{Z_N}) L_c + X_m) + \\ & (-\sin(\theta_{X_N})\sin(\theta_{Y_N})\sin(\theta_{Z_N}) + \cos(\theta_{X_N})\cos(\theta_{Z_N}))(\sin(\theta_{X_m})\cos(\theta_{Y_m}) L_c + Y_m) - \\ & \sin(\theta_{X_N})\cos(\theta_{Y_N})(-\cos(\theta_{X_m})\cos(\theta_{Y_m}) L_c + Y_m) + \\ & (-\sin(\theta_{X_N})\sin(\theta_{Y_N})\sin(\theta_{Z_N}) + \cos(\theta_{X_N})\cos(\theta_{Z_N}))\ Y_m + \\ & (\sin(\theta_{X_N})\sin(\theta_{Y_N})\cos(\theta_{Z_m})\cos(\theta_{X_m})\sin(\theta_{X_m}))\ X_N - \sin(\theta_{X_N})\cos(\theta_{Y_N})\ Z_N \end{aligned} \quad (14)$$

$$\begin{aligned} \boldsymbol{b_{34}} = {} & (-\cos(\theta_{X_N})\sin(\theta_{Y_N})\cos(\theta_{Z_N}) + \sin(\theta_{X_N})\sin(\theta_{Z_N}))(-\sin(\theta_{Y_m}) L_c + X_m) - \\ & (\cos(\theta_{X_N})\sin(\theta_{Y_N})\sin(\theta_{Y_N}) + \sin(\theta_{X_N})\cos(\theta_{Z_N}))(\sin(\theta_{X_m})\cos(\theta_{Y_m}) L_c + Y_m) + \\ & \cos(\theta_{X_N})\cos(\theta_{Y_N})(-\cos(\theta_{X_m})\cos(\theta_{Y_m}) L_c + Z_m) + \\ & (\cos(\theta_{X_N})\sin(\theta_{Y_N})\sin(\theta_{Y_m}) + \sin(\theta_{X_N})\cos(\theta_{Z_N}))\ Y_N + \\ & (-\cos(\theta_{X_N})\sin(\theta_{Y_N})\cos(\theta_{Z_N}) + \sin(\theta_{X_N})\sin(\theta_{Z_N}))\ X_N + \cos(\theta_{X_N})\cos(\theta_{Y_N}))\ Z_N \end{aligned} \quad (15)$$

Fuzzy Controller

The system presented in this article (ship-manipulator) is clearly a system with several non-linearities, which implies a big task when it is necessary to choose a correct controller. This type of problem is studied in many papers (*Jie L, 2005; Dongbin z, 2004; Yang K, 2006*), where different types of nonlinear controllers are used to control cranes and cargo systems, especially those working on container ships.

One of the techniques, also implemented to control the crane, is fuzzy logic (*Abbod M, 2000*). It is a very intuitive way to put all the knowledge for the specialist in the controller behavior. The process of designing a fuzzy control system starts by taking the knowledge of the procedure for the transfer of cargo and the type of cargo and then following the basic steps:

1. Define Input and output variables.
2. Define fuzzy sets.
3. Define fuzzy inference system.
4. Define fuzzy controller rules.
5. Test to improve the controller.

For an efficient control using fuzzy logic, it is mandatory to adequately allocate the input variables, the range and the relevance of the rules that generates a correct output value, in this case the speed of the manipulator.

Input and output variables

In any project based on a fuzzy logic controller, it is required to determine the relevant variables for the problem that can be measured (inputs) and those that can be controlled. From the moment when the input and output variables are defined, it is important to also determine a reasonable range of values that can occur (due to the physical restrictions). For the problem presented, the set of variables are.

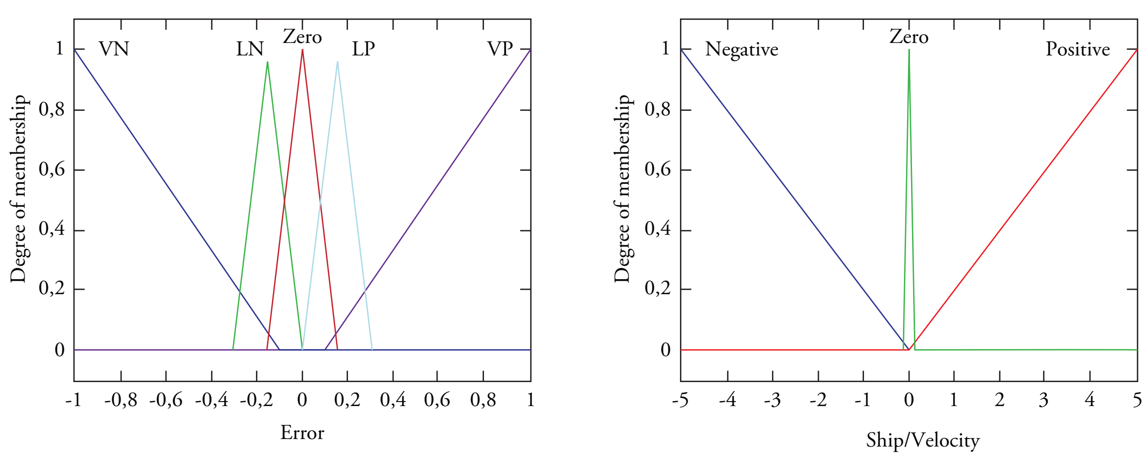
- Error between the set point and the actual position
- Ship velocity
- Manipulator velocity

This project uses two independent fuzzy controllers, one for the Y axis and other one for the Z axis; both have the same inputs, outputs, and rules.

Membership functions

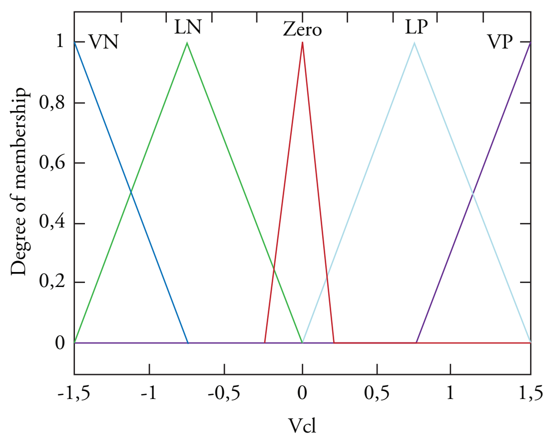
The fuzzy controller uses only triangular functions. For the function set, five triangular limited graduations of -1 to 1 were used. They are called *Very Negative, Negative, Zero, Positive, Very Positive*. For the pertinence function of the speed of the ship, represented by the Fig. 4, three functions of triangular limited relevance from -5 to 5 were used: *Negative, Zero, Positive*.

Fig 4. Fuzzy sets



As in previous cases, Fig. 5 shows the output velocity of the triangular graduations for the manipulator, limited to -1.3 to 1.3 these values were selected based on the recommendations in the literature on the speed found in devices manipulating similar loads, which requires a maximum of 2 m/s. The sets used are called: *Very Negative, Negative, Zero, Positive, Very Positive*.

Fig 5. Output set



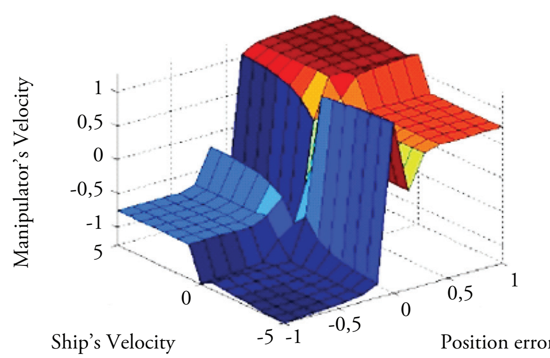
Rules

Setting the controller rules is one of the most important phases to correctly achieve the set point because any error can reproduce an undesired response. Table 1 show the rules used for the control of the proposed system.

At this point, it is important to mention that the set of rules presented in Table 1 is the result of an optimization design process; this process includes the technique called simulated annealing that shows its utility in diverse kinds of problems (*Dutra M, 2008*).

For a better view of the behavior of the rules, Figure 6 shows the value of the output called "speed of the actuator" for the different levels of contributions from both linguistic variables called "error of position" and the so-called "ship speed".

Fig 6. Output set (b)



The general characteristics of the controller can be implemented, as given in Table 2.

Results

The controller developed in this project reduces the load oscillations in an offshore operation. To achieve that goal, the previously described manipulator was implemented to control cargo motion during offshore procedures.

To see the complexity of handling cargo without a control system, see Figs. 7 and 8. They represent the

Table 1. Controller rules

		Position Error				
		Very Negative	Less Negative	ZERO	Less Positive	Very Positive
Ship Velocity	Negative	Very Negative	Very Negative	Very Positive	Zero	Less Positive
	Zero	Very Negative	Less Negative	Zero	Less Positive	Very Positive
	Positive	Less Negative	Zero	Very Negative	Very Positive	Very Positive

Table 2. General characteristics

Characteristic	Value
Inputs	21
Outputs	20
Rules	Triangular
Fuzzy sets	Minimum
Or	Maximum
And	Centroid
Defuzzification	

Table 3. Test Parameters

Ship	Container
Maximum wave height	5 m
Wave frequency	0.2 Hz
Rope Length	10 m
Load mass	10,000 kg
Maximum velocity for the actuators	2 m/s

different types of fluctuations of the components of this mechanism without action of the manipulator. The conditions of the simulation are shown in Table 3. The sea conditions on Table 3 are very important because those perturbations excite all degrees of freedom of the system; Fig. 7 represents the load movement in the direction of the Y and Z axes under roll excitation. Fig. 8 represents the same movements in Y and Z axes under excitation in all the degrees of freedom.

Fig. 7. System without control (a)

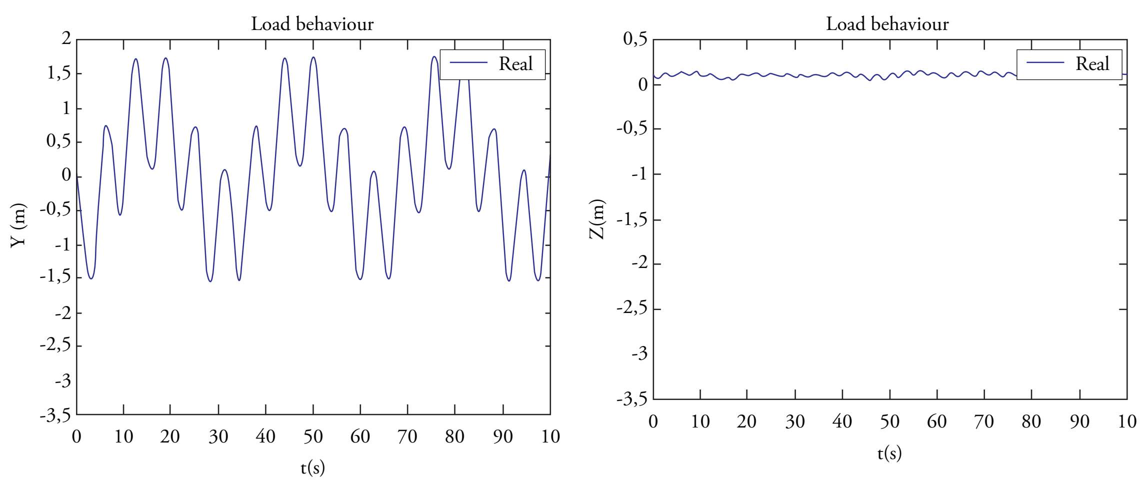
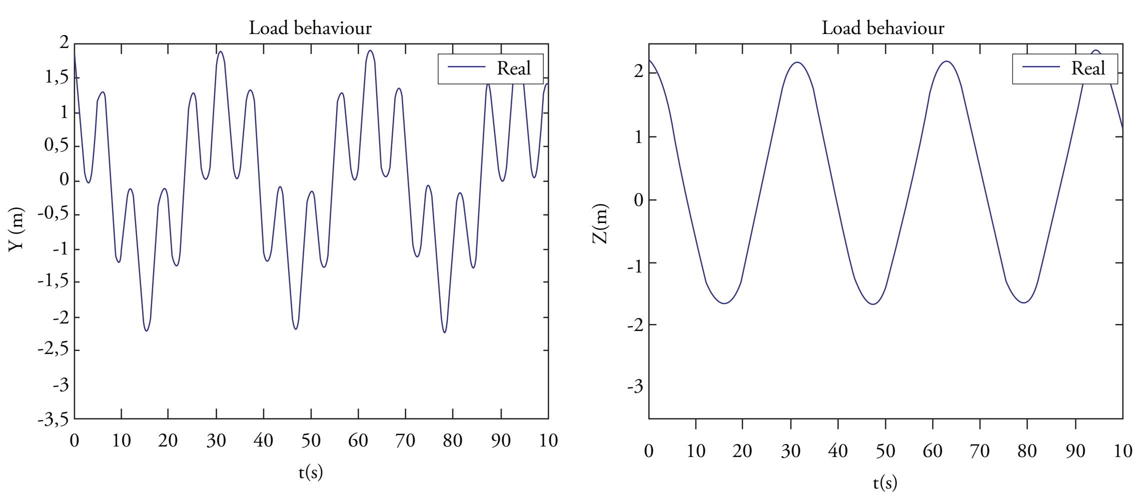


Fig. 8. System without control (b)



Considering the position, the results obtained by using the control system based on fuzzy logic are presented in Fig. 9 and Fig. 10. Both show good behaviour, reducing the oscillations of the load to only 5% for the amplitudes of disturbances.

Fig. 9. Controller situation for the case shown in Fig. 7

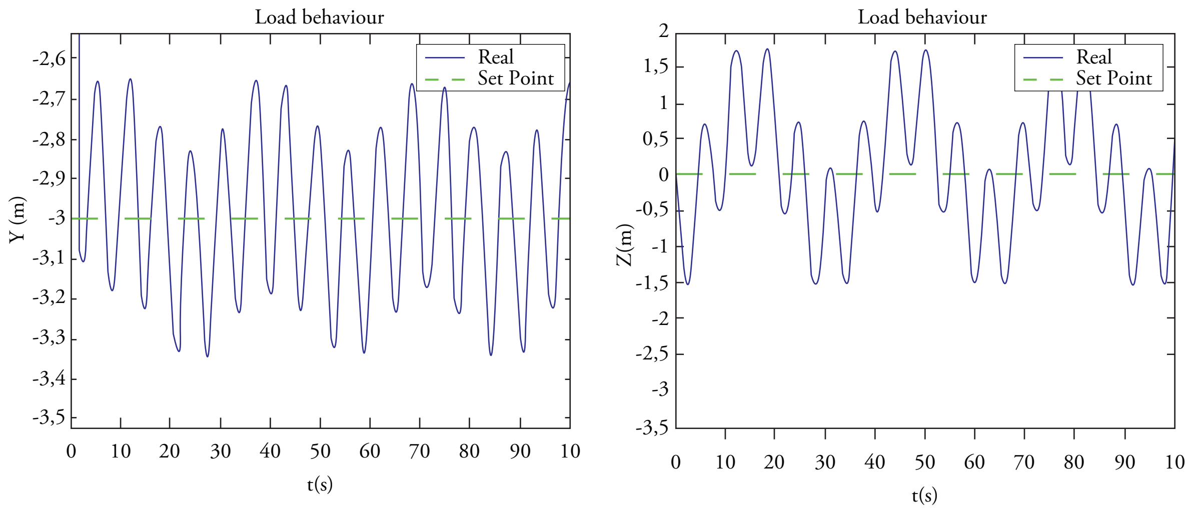
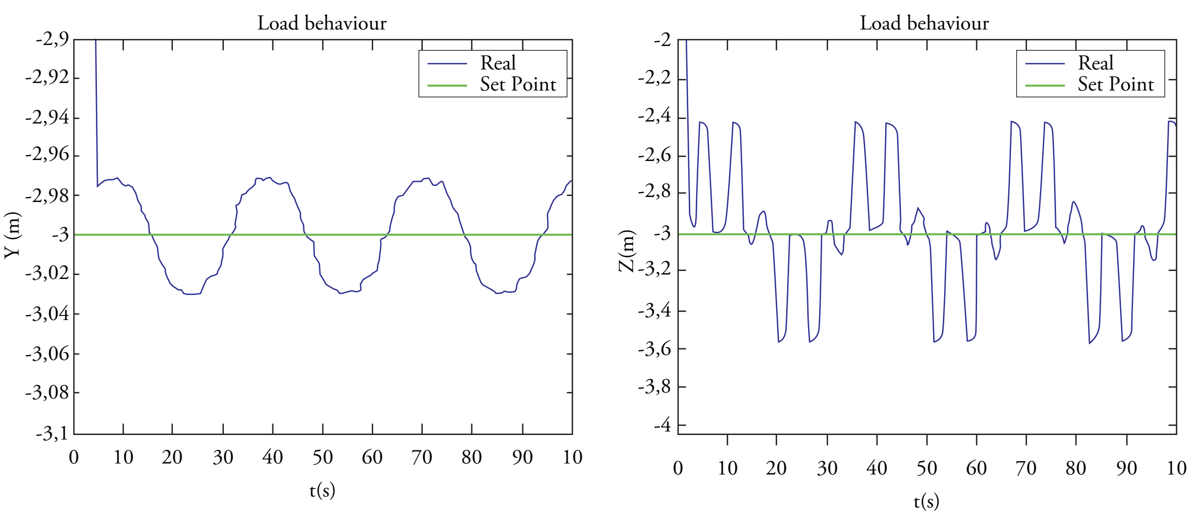


Fig. 10. Controller situation for the case shown in Fig. 8



Conclusions

This paper shows the analysis of the dynamics during offshore loading transfer operations. Offshore operations have a large degree of complexity because of their nonlinear dynamics.

Because of that, it was mandatory to implement a nonlinear controller, based on fuzzy logic.

The fuzzy controller stabilizes the load at the desired point relatively quickly, as the results presented in Section 4 indicate. The effectiveness of the control generates good expectations for practical implementations, even knowing that some disturbances under real conditions have not been considered.

References

ABBOD, M. F., MAHFOUF, M., KEE, C. H., 2000, Fuzzy logic-based anti-sway control design for overhead cranes. Neural computing and applications.

DONGBIN, Z., DIANTONG, L., JIANQIANG, Y. 2004, Adaptive sliding mode fuzzy control for a two dimensional overhead crane. Mechatronics.

DUTRA, M. S., LACHE, I. S., PRIETO, L. D. 2008. New technique for inverse kinematics problem using Simulated Annealing. EngOpt 2008. Rio de Janeiro. Brazil.

FOSSEN, T. 1994. Guidance and Control of Ocean Vehicles. JohnWiley and Sons, New York.

GROOM, N., ROBINNET, D. 2002. Pendulation control system and method for rotary boom crane. Patent No US 6,442,439 B1.

JIE, L., GUANGFU, S., KLEEBERGER, M. 2005. Complete dynamic calculation of lattice mobile crane during hoisting motion. Mechanism and machine theory.

MAN BW DIESEL A/S. 2005. Propulsion trends in container vessels. Man BW diesel a/s industrial manual reference.

NOTTEBOM, T. 2004. Container shipping and ports: An overview. Review of Network Economics.

SPHAIER, S. H. 2005. Hydrodynamics. Federal University of Rio de Janeiro.

VERSCHOOF, J. 2002. Cranes - Design, Practice and Maintenance. Professional Engineering Publishing Limited. London and Bury St Edmunds UK.

YANG, K. S., YANG, J. H. 2006. Adaptive coupling control for overhead crane systems. Mechatronics.

On maritime transport costs, evolution, and forecast

Acerca de los costos de transporte marítimo, su evolución y pronósticos

Gerardo Polo [1]

Abstract

During recent years of economic euphoria, globalization, motor of development, has been possible due to the existence of a fast, efficient, and economic maritime transport. The technological development based on scale economies, improvement of cargo-handling systems, and specialization has allowed putting on the market vessels with very competitive costs. In these years of a bright freight market, increased costs seemed not to be of much concern, so that the problem was not approached with the necessary firmness. Nowadays, things have changed: freight rates have sunk, prices of ships have fallen, and the crisis has reached ship owners. The costs, nevertheless, are still rising, with the exception of 2009 in which, for the first time in ten years, costs of operations were sensibly reduced. In the paper, the evolution of the main components of the costs of the maritime transport are analyzed, studying the current situation of such, as well as the forecasts for the near future.

Key words: Maritime transport, Costs, Globalization, Operation costs, Opex

Resumen

En los pasados años de euforia económica, la *globalización*, motor del desarrollo, ha sido posible gracias a la existencia de un transporte marítimo rápido, eficiente y económico, propiciado por un desarrollo tecnológico basado en las economías de escala, la mejora de los medios de carga y descarga y la especialización. Ello ha permitido poner en el mercado buques con costes muy competitivos, cuyo incremento, en un boyante mercado de fletes parecía no preocupar demasiado, por lo que no se le hizo frente con la necesaria firmeza. Hoy en día, las cosas han cambiado: los fletes se han hundido, los precios de los buques han caído y la crisis ha alcanzado a los navieros. Los costes, sin embargo, han seguido su línea ascendente, con la excepción del año 2009, en el que, por primera vez en diez años, se experimentó una reducción sensible de los costes de operación. En el trabajo se analiza la evolución de los principales componentes del coste del transporte marítimo, la situación actual de éstos, así como las previsiones para el futuro próximo.

Palabras claves: Transporte marítimo, Coste, Globalización, Costes de operación, Opex

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Introduction

The operating costs of ships have traditionally been a topic difficult to investigate for lack of reliable data. In fact, at the beginning of my professional life, many ship owners thought that it was too delicate a matter and were reluctant to furnish said data, even in relative terms. Fortunately, things have changed and nowadays there are trustworthy sources providing valuable information to study the evolution of those costs. And this is a matter of maximum importance because, in a globalized market, such as that of the maritime transport, competitiveness is the main weapon that allows ship owners to reach the comparative advantages against their competitors. Of course, it is quite necessary to have benchmarking data with regard to what is being done in other places -often very different, very distant, and with cultures and ways of life very diverse from ours. This way, one can get at least a base to build the business framework to develop the shipping activity.

On the contrary, important changes that have taken place in nearly all economic sectors, but especially in the maritime sector, as a consequence of the world economic crisis, have produced significant modifications in the operating costs of ships, which have to be considered not only by the ship owners, who carry out the activity of maritime transport, but also by the rest of the participants of the maritime industries: shipyards, auxiliary industry, ports, etc., whose managerial developmentis strongly tied to that of the shipping activity and, therefore, pressed for all things that affect it.

Namely, in the past years, an important escalation of costs has taken place in the international maritime market, which has led a great number of ship owners to situations of difficult survival. Does this have something to do with the rest of the maritime industries stated above? Certainly yes, because ship owners have ordered the building of new vessels in shipyards and the continuity of the work is seriously threatened by the financial situation of the former; the auxiliary industry, ship suppliers, etc., also creditor of the ship owners; and of course banks, who granted credits for the construction of ships, credits that can be difficult to recover; for the world trade, whose exports and imports depend mainly on the availability of maritime transport that is not only efficient, but specially economic and reliable, among others.

It again places on the table the problems of the operating costs of ships, a matter of enormous importance for ship owners and for the whole international economy. This is why we decided to present this paper on the operating costs of maritime transport, its evolution throughout the past years and the forecasts that, nowadays, experts in the sector conduct for the future evolution of these costs.

The cost structure of maritime transport

The traditional subdivision of the operating costs of ships between fixed costs and voyage costs is well known.

In fact, according to the classical subdivision of maritime economics, costs can be divided as far as the production volume is concerned and so the costs are considered fixed when they are independent from the above-mentioned volume and variables when they depend on the same one. Nevertheless, it is difficult to find in maritime transport costs of voyages that are really proportional to magnitudes related to production: namely, and always with some restrictions, the bunker consumptions could to be considered as proportional to the distance -or to the time employed to cover them at a certain speed- and certain costs relative to the loading/ unloading of cargo proportional to the transported tonnage or, perhaps better, moved in every port; on the other hand, it is not clear at all what should be considered to be the production volume in the maritime transport: the transported tons?, the miles navigated?, the produced tons? the crossed miles?, the product of tons by miles? These are the reasons why it is best to refer not to the production volume, - difficult to fix in the maritime transport-, but to the level of activity, concept into which the different above referred magnitudes can fit with more precision.

Thus, the cost of maritime transport can be classified as fixed costs and variable costs (in our case, voyage costs); within these, some of their components can be considered proportional to magnitudes more or less related to the level of activity. Independent from the previous ones, there are costs of sales, which are generally proportional to the earnings or commissions on the sales, but these are often considered a reduction of income, which are entered by the net amount.

From a strictly theoretical point of view, the fixed costs, independent from the activity developed, remain constant even though there is no activity; in other words, though the ship remains idle. But, as far as our classification is concerned, we will recognize as fixed costs those whose objective is to maintain the ship in seaworthy conditions to offer transport services, even though the vessel can be laid-up. So, the ship must have its crew on board, certificates in order, engines in operating conditions, insurance policies in order, etc., (aspects to a certain extent damaged when a ship is really laid-up). Bearing in mind these issues, the fixed costs will really have such a character, and it will only be necessary to add the voyage costs to obtain the total costs.

The voyage costs -or variable costs- are a function of the activity the ship develops, taking place only when the vessel is in service. Unlike the fixed costs, they depend on every specific voyage and, especially, on the ports of call, distance crossed, cargo handling operations, the possible need of passing some channels, etc.

Within the fixed costs it is necessary to distinguish the capital costs –CAPEX, costs derived from the property of the ship– and the running costs or fixed operation costs –OPEX, costs that are necessary to have the vessel ready for operation–: by means of both types of costs the operator fulfils his basic aim already indicated of having the ship seaworthy to give the service of transport. Depreciation and financial costs are the capital costs; and crew, insurance, maintenance and repairs and the administration costs are the running costs or operation costs.

Certainly, as soon a voyage starts, the ship owner incurs in voyage costs, costs that can be classified into a single category of voyage costs or segregating from them the cargo-handling costs.

The voyage costs, always depending on the specific trip, are costs inherent in the activity of the operator, that is to say, they are costs for the ship owner or the time charterer to develop the maritime activity of the voyage.

Among the voyage costs, the following items are usually distinguished: the bunkers consumptions, port costs, channel tolls, and cargo-handling costs.

Ships in the open tramp market usually do not assume cargo handling costs, as they are chartered on FIOST conditions, but when ships are on regular service, the ship owner includes in the freight the cost of handling the goods for loading and unloading. In the regular services, voyage costs are also fixed, as the ships repeat itineraries and scales, so port costs and channels tolls, as well as bunker costs are fixed costs and the cargo handling costs are the only variable costs.

Dependence factors

In any case, a brief analysis of the above referred cost structure shows that a very important part of the fixed costs is a direct function of the building cost of the ship (through depreciation, interests and insurance costs), though the rest depends on multiple factors of diverse types. On the other hand, the main components of the voyage costs –that can be grouped in two big items: bunker consumption during the navigation time and costs produced during the stay in port– depend, to a great extent, on the speed of the ship, the prices of the fuel and the time of stay in port.

So, the most important factors of the maritime transport costs show something simple, but often forgotten. That time of navigation, time in port, and cargo handling costs constitute the basic framework of costs of the shipping economy. All this based on a few technical factors of the costs -speed, specific consumptions, general arrangement

Table 1. Cost structure of maritime transport

Tramp	Cost Concept	Regular Lines
Fixed Costs	***Costs of capital*** • Depreciation of the ship • Interests of financing credits • Other financial costs	Fixed Costs
	Running costs or fixed operation costs (OPEX) • Crew • Maintenance and Repairs • Insurance • Administrations costs • Proportional costs	
Voyage Costs	Bunker consumption -Non-proportional costs • Port costs • Chanel tolls • Other	
Voyage Costs (eventually)	• Cargo handling costs • Taxes and other cargo costs • Multimodal equipment • Land transport	Cargo-related Costs Cost of Special Systems (eventually)

of ship and cargo handling systems (on board and in port, infrastructure)- and a few economic factors on which, once the ship is on operation, it is difficult or impossible to be changed or, in any case, action on these is very limited -fixed costs of the ship, fuel prices, costs of port, cargo handling costs-. All of them outline the final cost structure of the maritime transport. Schematically, it is possible to put:

Table 2. Technical and economics factors of maritime transport

	Technical factors	Economic factors
Navigation	• Ship's speed • Specific consumptions	• Fixed cost of ship (daily) • Bunkers price
Stay in Port	• General arrangement and cargo handling system (ship and port) • Specific consumptions	• Fixed cost of ship (daily) • Bunkers price • Port expenses • Cargo handling costs

As far as the economic factors is concerned, it must be clear that ship owners have very few possibilities of modifying them to act on the evolution of their costs, so the factors on which those depend are, fundamentally, the price of acquiring the ship, its financing conditions, and a series of factors completely beyond the ship owner's influence, given that they are imposed by the market of crude oil and of marine fuels, the ports, etc.; only, but with numerous limitations, ship owners can act on their fixed costs of operation (crew, maintenance and repairs, insurance, etc.); the rest of the costs escape the action of ship owners, who can do nothing to control them.

And as for the technical factors, it is quite clear that, except the eventual alterations in the general arrangement of the ship to adapt it better to the traffic giving her some specific cost saving system or an improvement of the productivity, such as the installation of new cranes to make a better performance of cargo handling operations, from a practical point of view the shipowner only can modify his costs by means of the alteration of the service speed, and to this respect, the slow steaming is a good proof of it.

In any case, it can be seen that probably the main specific characteristic of the costs of maritime transport is the remarkable inflexibility, which is one of the major difficulties to face the traditional crises of the freight market.

Evolution of costs

During the last years, and up to the great economic crisis begun in the middle of 2007 and generalized on the following year, and affecting the whole international economy, the freight market, basis of the globalization, grew up to unbelievable levels in many years, with values of the indexes that had never been reached before. In this context, during these years of prosperity, the costs –nearly all the costs– grew very remarkably. And the shipowners, more attentive to the freight market than to their internal costs did not fight against this problem so important for them.

First of all, the rise of the fuel prices is well-known, whose evolution during recent years was really devastating for the shipping economy: the 380 Cst fuel oil, whose price in Rotterdam in 2003 reached 150 US Dollars per metric ton, reaching 720 US Dollars per metric ton in 2008, when the price of the barrel of crude oil reached 146 US Dollars. And though later the pressure diminished, we are now in a new upward stage, with fuel oil prices that at the beginning of January, this year have surpassed 500 US Dollars per metric ton, so the invoice of the bunkers continues being very high, and the lines of big container ships have reduced the speed of service, incorporating new vessels in their lines, while the oil tankers are also considering to reduce their speeds and to return to the slow steaming.

On the other hand, the evolution of the Euribor during the last years has become another important factor in the increase of the costs, in this case the capital costs. In fact, the average of the one year Euribor, which in 2003 was 2.34%, was 3.44% in 2006, 4.45% in 2007, and in 2008 it went beyond 5.50%. That led, between 2003 and 2008, to cost increases of interests close to 130%, which translated to increased needs for cash flow to take care of the debt between 12 and 13%. Fortunately, the fall of interest rates from the generalization of the crisis has again reduced the capital costs, which are now even below those existing in 2003, in spite of the light recovery produced in Euribor during recent months. Anyhow, at the end of this year, or maybe during the following year, substantial increases of interest rates will be seen once more, given that as soon as the economies recover their production pace, the danger of inflation will have to be attacked by means of a new increase of interest rates.

But it has not been only a problem of fuel or financial costs. Also, other costs of operation - mainly crew, maintenance and repairs, supplies and insurance - have followed the rise of those costs. The year 2007 was particularly sensitive to these increases: according to Moore Stephens (7), the average increase of the costs of crew was over 10%, though in some types of ships the figures reached were above that percentage - namely, the container ships saw a 20% increase in this item. Costs of supplies also experienced important increases, over 16%, though below the figure of the previous year, which reached a 20% increase. As far as maintenance and repairs are concerned, the average increase in 2007 was 12%, though with differences among the different types of ships. And the insurance costs also rose, experiencing an average 7% increase. Globally, the average increase of the costs of operation of the fleet through the year 2007 was 11.2%.

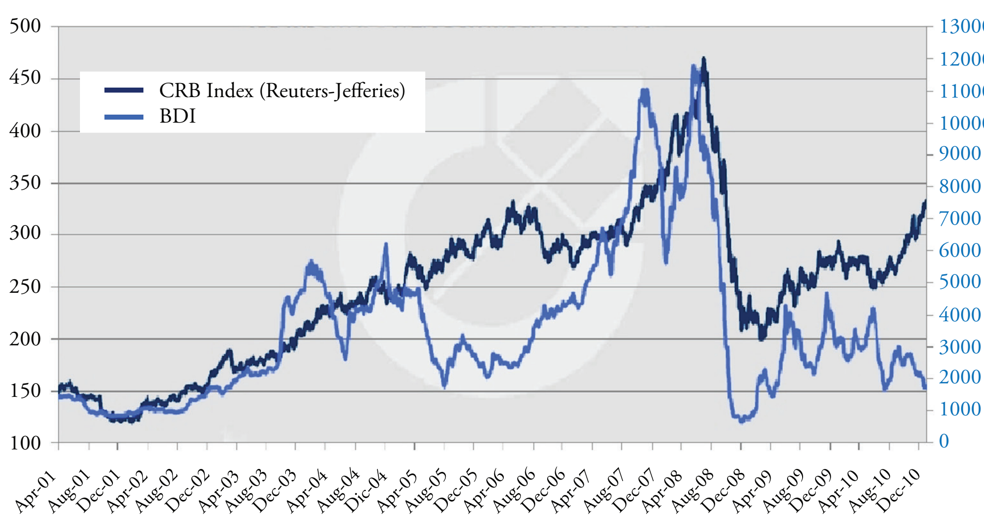
But it has not only been a matter of one year. Between 2003 and 2008 -the years of the freight market boom -the running costs of operation of the ships (crew, maintenance and repairs, insurance, etc.) endured very important increases. The following table shows the representative indexes of operations costs of bulk carriers, oil tankers, and container ships between 2000 and 2008, as well as the year-on-year percentage variations (also according to Moore Stephens).

As noted, the total increase of costs of operation during only eight years have been very important, namely 72% for bulk carriers and 84% for oil tankers. The container ships, whose statistics only reach 6 years, saw their costs grow to 73%. Percentages that correspond to rates of annual accumulative growth of costs between 7.0% and 9.6%, absolutely unbearable figures except under situations of a freight market boom; otherwise, they can collapse the economies of a great majority of ship owners.

Table 3. Evolution of running costs of operation of ships

	Bulk Carriers		Oil Tankers		Container Ships	
	Index	**%Change**	**Index**	**%Change**	**Index**	**%Change**
2000	100		100			
2001	101	1,0%	106	6,0%		
2002	96	-5,0%	109	2,8%	100	
2003	105	9,4%	113	3,7%	110	10,0%
2004	118	12,4%	125	10,6%	117	6,4%
2005	122	3,5%	132	5,6%	120	2,6%
2006	135	10,0%	144	9,1%	133	10,8%
2007	145	7,4%	160	11,1%	157	18,0%
2008	172	18,0%	184	15,0%	173	10,2%
Δ annual cum.		70,0%		7,9%		9,6%
Δ total		72,0%		84,0%		73,0%

Fig. 1. Evolution of Index of Commodities and Baltic Dry Index



What is the reason for such an important rise in costs? Simply because at the same pace of the growth of the economies of most countries, the prices of raw materials also rose in a immoderate way, so that not only the fuels -whose multiplier effect on the prices is clear and important -, but also aluminum, copper, nickel, silver, etc., that is to say, the main commodities of international trade, were multiplying their prices and their influence on the world economy. Especially, the evolution of the prices of coal, iron ore, and steel have had muchrelevance in this explosion of price increases.

Actually, the behaviour of the main commodities during these years was very much alike that of the BDI (Baltic Dry Index), which is considered to be the most suitable measure of the evolution of the freights corresponding to the dry bulk goods on the world market. A remarkable correlation can be observed, according to Cotzias, between the BDI and the CRB Index Reuters-Jefferies, considered one of the most accurate indexes of raw materials on the international trade market.

Fig. 2. VLCC Costs 1990-2010

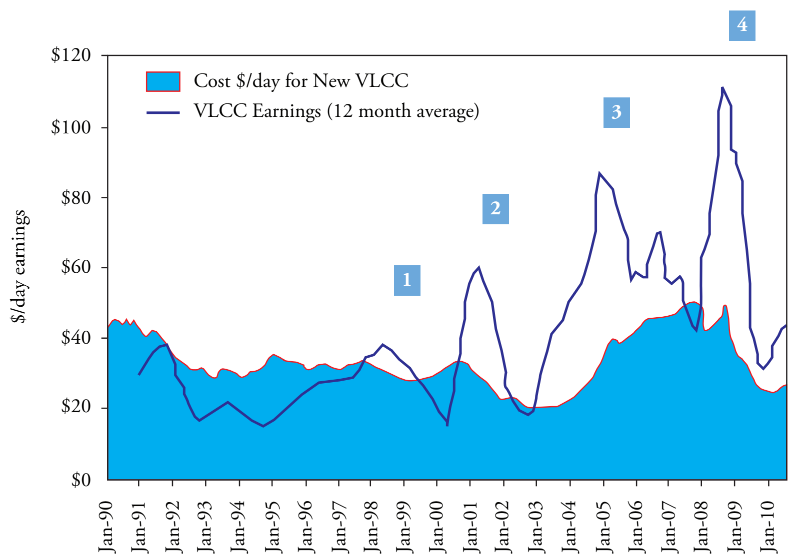


Fig. 3. Cape Costs 1990-2010

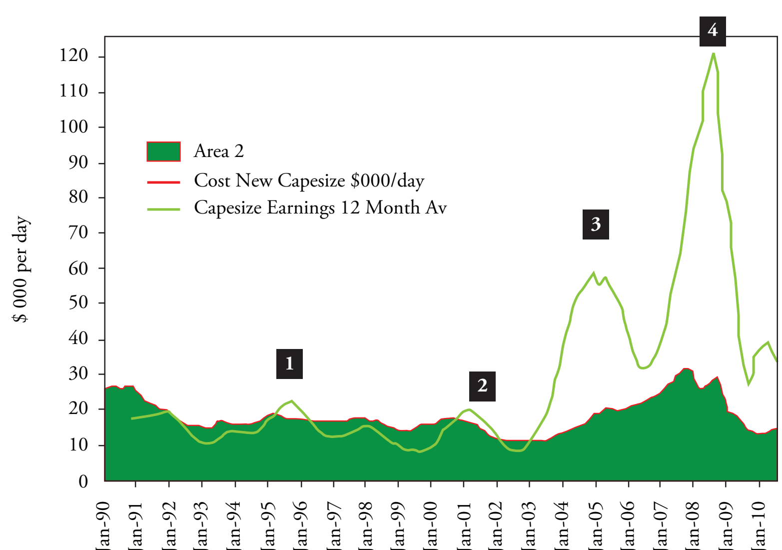
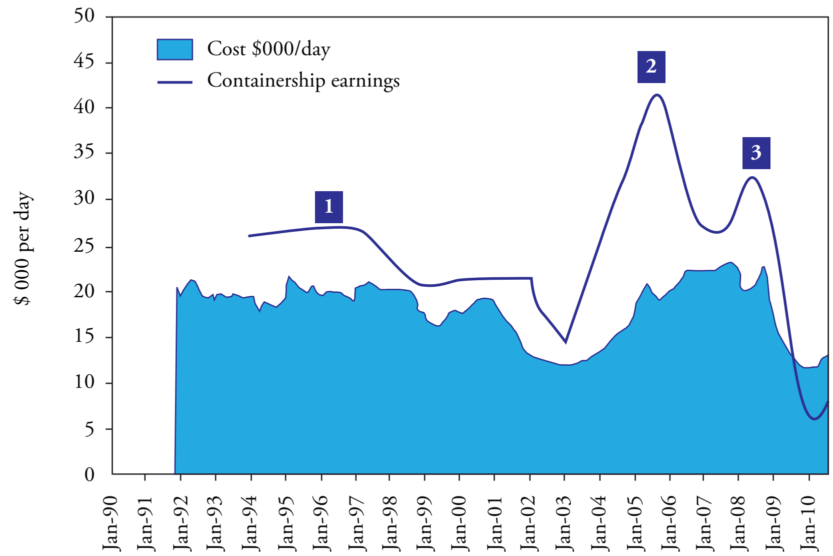


Fig. 4. TEU Container Costs 1994-2010



On the other hand, it is certainly interesting to observe the evolution of the fixed total costs of operation of ships (capital costs plus operation costs) throughout the last 20 years, according to Clarksons (information presented by Stopford at the end of last year 2010). These calculations were made with capital costs computed on a 20-year depreciation period, interest at Libor rate, and all calculations referred to the price of a new building in every month of the year.

The information corresponding to three types of ships (VLCC oil tanker, Capesize bulkcarrier and 3.300 TEUs containership) is illustrated in the lower part of the graphs, that show in US$/day the total cost of each type of ship, in front of the curve of the corresponding income (TCE), left apart in this moment. In this figures we can see that between 2003 and 2008, the years of the freight boom, the total costs per day of the ships grew between 100% (3300 TEUs containership) and 200% (VLCC oil tanker and Capesize bulkcarrier) to a great extent because, besides the rising of the operation costs, the capital costs[1] also suffered an important augment.

Summary and forecast

The costs of operating a ship, which, as explained above, can be divided into fixed costs and voyage costs, have experienced remarkable growths especially important since 2003. Let us summarize their evolution.

The capital costs depend mainly, as explained before, on the purchase price of the ship. This is a parameter closely correlated with the evolution of freight index. In the years of the last boom, astronomic prices were paid not only for new ships or ships still being built in the shipyard –between 50 % and 100 % above the price of the shipyard for a newbuilding–, but, in addition, in the second hand market prices reached figures higher to those corresponding to newbuildings –bulk carriers 5 and 10 years old and some 5 years old oil tankers– and even old ships of 20 years of age, were sold at prices between 75 % and 80 % of the newbuilding prices by those dates. We refer to the first half of the year 2008. This was possible because the market was paying extraordinarily high freights which allowed a very quick recovery of the capital, in spite of that the old ships required an annual income much higher than the new ones to face to the capital payments (devolution of principal and interests of the debt). The information included has been taken from Compass (3) and corresponds to October, 2007, but figures were even higher in the first half of 2008.

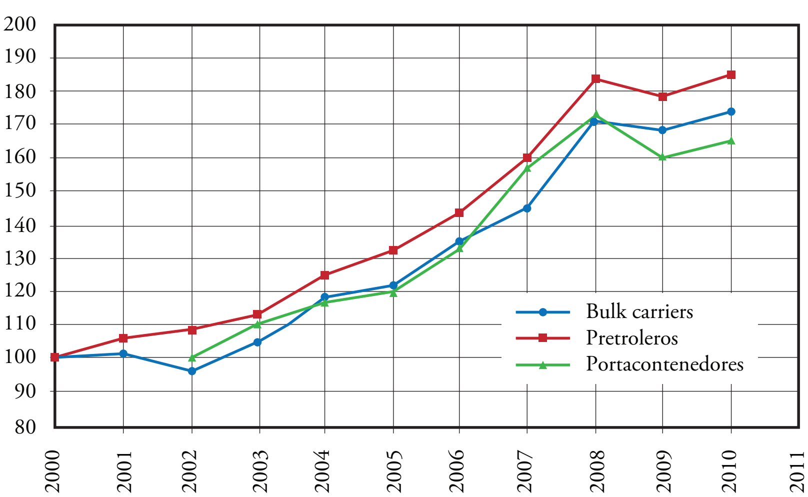
Table 4. Newbuilding and second hand prices of ships in October 2007

Tankers	NB	Prompt Resale	5 Years	10 Years	20 Years	12 Month T/H
VLCC 300,000 dwt	$143,0m	$153,0m	$133,0m	$105,0m(DH)	$33,0m(SH)	$50,000PD
Suezmax 150,000 dwt	$88,0m	$105,0m	$96,0m	$75,0m(DH)	$26,0m	$42,000PD
Aframax 105,000 dwt	$70,0m	$78,0m	$67,0m	$55,0m(DH)	$20,0m(SH)	$32,000PD
Panamax 70,000 dwt	$64,0m	$66,0m	$56,0m	$48,0m(DH)	$17,0m	$27,500PD
Product 47,000 dwt	$52,0m	$58,0m	$53,0m	$43,0m(DH)	$17,0m	$25,000PD
Bulk Carriers						
Capesize 170,000 dwt	$96,0m	$160,0m	$133,0m	$101,0m	$72,0m	$185,000PD
Panamax 74,000 dwt	$50,0m	$100,0m	$84,0m	$71,0m	$40,0m	$89,000PD
Supramax 52,000 swt	$43,0m	$84,0m	$72,0m	$56,0m	$34,0m	$67,000PD

Source: Compas

Evidently, the fall of the market has been a hard knock for the shipowners, many of which have not been able to support the new conditions, some have been led to sell their ships with big losses and others even have disappeared. Banking also suffered much of the problem, as financial basis of the investments, and many financial institutions have been immersed in the crisis. Certainly, the fall of the market has also brought a better price of the ships, though the financing of them has become much more difficult to obtain and the number of operations has been reduced.

Fig. 5. OPEX indexes evolution 2000-2010

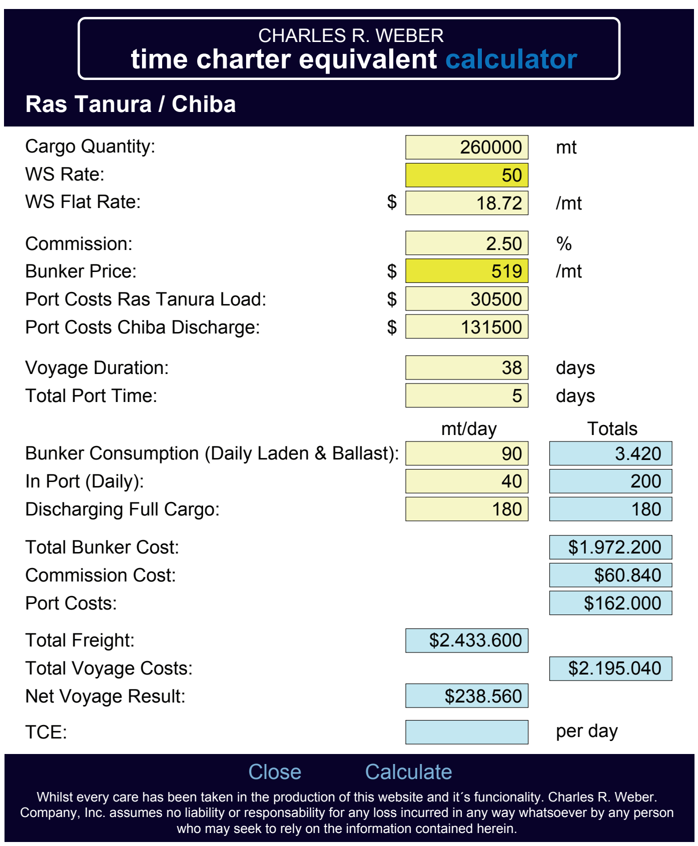


Anyhow, every ship is a particular case, and although the general evolution of prices has been the indicated one, the fact is that every ship owner has acquired ships at different prices, in different moments and with different financing conditions.

The evolution of the running costs or fixed costs of operation (Opex) of ships during the last 10 years shows a nearly continuous rise. The problem now is that in the middle of the crisis –although with the exception of the year 2009– the costs continue increasing.

Fig. 6. Evolution of crude oil price and bunker price in Rotterdam

Fig. 7. Calculation of tce of VLCC RAS TANURA / CHIBA



Nowadays, with information at the beginning of January, 2011, some oil tankers are in a serious situation, as the calculation of the TCE at the WS rates in force in the above-mentioned date shows that in a trip Ras Tanura - Chiba the fuel consumed by a VLCC has a cost equivalent to 75% of the gross freight [source: Charles R. Weber (2)] and the TCE is below 10,000 US$/day, which means that the ship does not cover its daily running costs.

The fact is that already the price of a metric ton of fuel-oil is on 510 dollars² and slow steaming continues spreading. Namely, after the first cut to about 20 knots in the regular lines of big container ships, widely extended in the above mentioned market, and a the second fall to 17,2 knots, shipowners are now studying the proposal of Germanischer Lloyd –supported by Bureau Veritas– of limiting the speed of these vessels to approximately 14 knots –although someone is also talking about going to just 12 knots–, in what it has been called super-slow steaming.

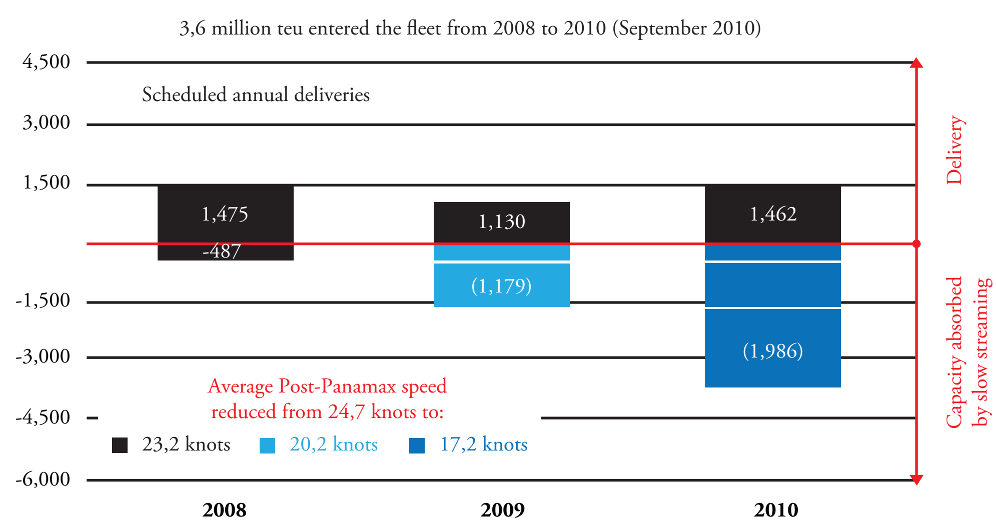
All that has a decisive importance in the relations between supply and demand, according to Danish Ship Finance (5) the artificial or apparent reduction of supply due to the slow steaming to 20.2 knots gave employment for big container ships in 2009 of about 1.200.000 TEUs; whereas, a new fall of the speed of operation of the post-panamax container ships to just 17.2 knots generates additional employment for about 1.900.000 TEUs. So, bearing in mind that the excess of supply of big container ships, with information up to September, 2010 is about 3.600.000 TEUs (26% of the existing fleet), the evolution of the market of big container ships, with an apparent recovery in the last months, shows simply an adjustment between supply and demand derived, not from the increase of the latter, but from the decrease of the fleet productivity and, therefore, from the artificial reduction of the former by means of slow steaming.

Up to now, we have seen mainly what happened until the collapse of the freight market, which took place in the middle of 2008. But, what happened in 2009? This year was the first after a long time in which the running costs of ships diminished; not too much, but appreciably. Namely, in the bulk carrier sector there was a reduction of 2.3%, leaving the index at 168, in the oil tanker group the decrease was 2.7%, with the index remaining at 179, and in the container ships the cost drop was more important, at 7.5%, placing the index at 160.

This is, as far as bulk carriers and oil tankers is concerned, slightly below Drewry's forecasts (6), whose calculations for the year 2009 gave a cost reduction of 3.6% and of 3.5%, respectively; also, in container ships the figures are well above Drewry's predictions, whose average is 3.9%.

And what about the year just finished? In 2010, the costs rose again, in spite of the depth of the crisis in the maritime sector since 2008. Though we have no definitive data, the estimations show growth of the fixed costs of operation of 3.3% in bulk carriers, 3.1% in oil tankers, and of 3.2%

Fig. 8. Effect of low steaming on container regular lines offer



in container ships. And still worse are that the forecasts for the current 12 year, 2011, whose figures are not optimistic at all: increased costs of 3.6% in bulk carriers, 3.2% in oil tankers, and of 4.0% in container ships.

In contrast, for 2010 Drewry's predictions give minimal growth, practically a maintenance of the costs of 2009 and for 2011 major growth, near 2 to 3%, but also below Moore Stephens's estimations.

Where are we going in the present circumstances, with increasing costs and important reduction of freight rates? I think we are again going to live something already lived in other past crises, which led the maritime sector to situations of real distress, with significant economic losses, lay-up of vessels, scrapping, cancellation of building contracts, unemployment in shipyards, etc., circumstances that we are already seeing since more than two years ago.

References

BRAEMAR SEASCOPE. Market Information, Jan 2011.

C. R. WEBER. The Weber Report, Jan 2011.

COMPASS. Compass Weekly Report, Oct 2007.

COTZIAS. Economic Outlook Dec 2010.

DANISH SHIP FINANCE. Shippping Market Review, Oct 2010.

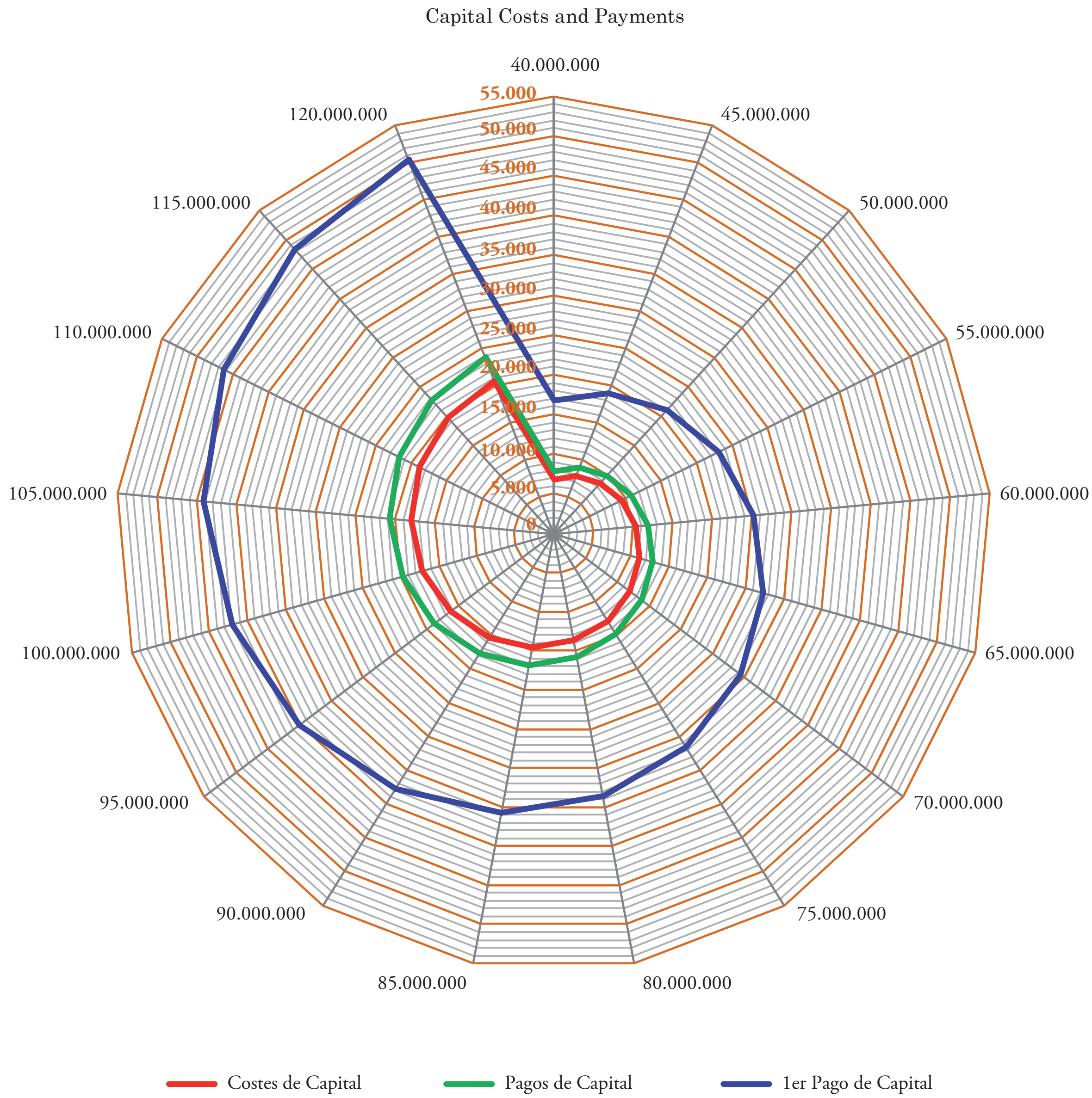
DREWRY. Ship Operating Costs 2009-2010.

MOORE STEPHENS. Op Cost 2010 Report and other previous Reports.

STOPFORD. A year of decisions for shipping - How will the markets develop?, FT Deutchland Ship Finance Conference, Hamburg, Sep 2010.

G. POLO. Capital Costs vs. Cash Flow: Keys to a better understanding of the freight market, Infomarine, No. 190, October 2011

[1] Detailed calculations with standard international market data on capital costs for vessels with prices ranging from 40 to 120 million dollars (29 to 87 million euro), with external financing and straight-line depreciation with a residual value of 10% the price of the ship after an useful life of 20 years, lead to the estimate of capital costs and payments schematically shown in the Figure below.



This shows the average capital cost, the average capital payment and the highest capital payment (which corresponds to the first year after the purchase) in dollars per day for different purchase prices ranging from 40 to 120 million dollars (29 to 87 million euro). This note is taken from Reference 9.

[2] One year later (first quarter of 2012), the price per metric ton was about or nearly 200 dollars higher, and it continues this tendency.

Shipbuilding and new requirements to reduce the environmental impact of ships: New technological challenges and business opportunities

Construcción naval y nuevos requerimientos para la reducción del impacto ambiental de los buques: nuevos retos tecnológicos y oportunidades de negocios

Publio Beltrán [1]

Abstract

New and increasingly demanding requirements of reducing the environmental impact of all types of ships from all countries, along with regulatory institutions like the new "Green Policy" of the European Union, leads to the development of a series of regulations/directives, which will immediately affect both the owner and the builders worldwide. This requires introducing modifications in the vessel design to fulfill these requirements and, ultimately, improve their exploitation while avoiding penalties and/or restrictions. Awareness of these requirements by some Spanish owners has allowed Spanish shipbuilding to be positioned strategically at the forefront of technology to fulfill these requirements. This work, after a review of those Directives affecting ship design, focuses on the presentation of the results obtained in two Ro-Ro Vessels. These vessels, given their design and performances, are a **"technological reference"** in the new scenario of high environmental performance requirements: Noise and vibrations on board, noise radiated to the harbor, and noise radiated to the water.

Key words: Ship Environmental Impact Reduction; Noise & Vibrations; Underwater Radiated Noise.

Resumen

Los nuevos y cada vez más exigentes requerimientos de reducción del impacto medioambiental de todo tipo de buques por parte de todos los países y organismos reguladores, como la nueva **"Política Verde (Green Policy)"** de la Unión Europea, llevan aparejados la aparición de una serie de reglamentaciones/directivas que afectarán, de forma inmediata, tanto a los armadores como a los constructores en el ámbito mundial. Ello hace imprescindible la introducción de modificaciones en los diseños de los buques que permitan cumplir con los nuevos requerimientos y en definitiva mejorar su explotación, así evitando penalizaciones y/o restricciones. La sensibilización de algunos armadores españoles con estos requerimientos ha permitido a la **construcción naval Española** posicionarse en la vanguardia y situarse estratégicamente para dar respuesta tecnológica a estos requerimientos. Este trabajo, tras un repaso de las directivas que afectarán al diseño de los buques, se centra en la presentación de los resultados obtenidos en dos buques RO-RO. Buques que por su diseño y prestaciones, constituyen un **"referente tecnológico"** en el nuevo escenario de requerimientos de altas prestaciones medioambientales: Ruidos y vibraciones a bordo, ruido radiado al puerto y ruido radiado al agua.

Palabras claves: Reducción Impacto Ambiental de los Buques; Ruidos & Vibraciones; Ruido Radiado al agua.

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Introduction

Growing social interest on the importance of **Control**, **Monitoring**, and **Improvement** of the environment has been the stimulus for different states to respond to this current demand. Like many other countries, the European Union (EU), also sensitive to these claims, has started the so-called **"Green Policy"**, whose main target is to establish directives or/and requirements to improve and maintain the environment. Withinthis new **"Green Policy"**, the EU has identified "ambient noise" [1] as one of the most critical factors to control, being all types of transport (land, air, and sea) the main polluting agents. Consequently, Noise and Vibration reduction in all types of transport constitutes one of the main objectives in the environmental improvement policy defined by the EU and the other countries involved in improving the environment.

Noise and Vibration emissions caused by vessels have several consequences: first, the emissions could lead to crew health disorders; they affect passengers and harbor surrounding resident comfort, as well as the working dynamics of the vessel. For fishing vessels, which are under no regulation in this aspect, several statistical studies are available, which reveal rates up to 70% of ear-related disorders among the crew. Secondly, known are the problems that some ship owners (national and international) have had due to complaints and reports of the excessive noise generated by the vessels when moor near highly populated areas.

Furthermore, the high level of Underwater Radiated Noise coming from a high rate of sea transport, and the fact that this aspect "has not been controlled", except for special vessels (Fishing Research Vessels- FRV), were revealed as the main causes of marine life and dynamic alteration, with its ecological and economic consequences for the marine environment and the coast line. It is experimentally verified that fish escape from these areas because of higher rates of underwater-radiated noise as a result of increased sea transport.

It is important to highlight that the most recent regulations/directives, as well as those pending **warn and obligate** ship owners and vessel operating companies to adopt all the possible measures that would guarantee worker health in relation to Vibration and Noise and in agreement with the new security and health rules. This has resulted in the incorporation of all these new environmental requirements in all the Contractual Specifications of the new shipbuilding practices.

In view of this new and restrictive Environmental Regulatory Framework, supposed to have an impact on the design of the new vessels and, consequently, on production costs, it is evident that Shipbuilding as a globalized industry has now a serious dilemma: it can either "look the other way" or "respond efficiently" to this newthreat, turning (what most would consider "a problem") into a "business opportunity "as long as we can "create an added value strategy". For those shipyards that will choose to "respond efficiently", they now face a "new specialized niche in the market" as a difference against their competitors.

In this work, after a detailed revision of the Current Regulatory Framework and the one about to be enacted (that will affect design and costs), we present **Study Case** of the results obtained as clear evidence of the correct training and preparation of the Spanish Marine Sector to address these new challenges.

New Regulatory Framework: Current and Future Community Requirements and Directives

This section aims to offer readers a summarized version of the Current and Future Regulations, with the clear target of raising awareness and approach to the resulting design and production costs. Besides the final price that will be defined according to market requirements and strategies, the author, based on his vast experience in this sector, considers that this knowledge will help readers to have a "more realistic" approach to the **"extra costs"** that will be assumed when signing a Specification where these new and demanding requirements appear.

Noise and Vibration Requirements Justification

In 1996, within the Fifth Community Program about environment, **"Towards a sustainable development"**, the European Union proposed, through the Green Paper on Future Noise Policy, [1] that the community strategy about acoustic pollution will be extended, reducing the origin emissions, developing information exchange, and reinforcing programs fighting against noise. In relation to these, on 22 June 2002, Directive 2002/49/CE [2] about the evaluation and management of environmental noise was passed. The main target of this Directive is to define a common approach for all the European Union countries with the aim of avoiding, preventing, and reducing the side effects of ambient noise exposure.

The vessels, as means of transport, generate noise and vibration and will be immediately affected in the Green Policy Framework, due to the "environmental impact reduction". This change will carry an ecological transformation in sea transport and, consequently, in the design of new vessels.

The growing concern in the European Union about improving occupational health conditions of sea workers, as well as reducing the environmental impact in the harbor area and improving marine environmental conditions have resulted in the promulgation of Rules, Policies, and Directives coming from maritime and labor organizations (International Maritime Organization (IMO), International Labor Organization (ILO)). Classification Societies (Bureau Veritas (BV), Det Norske Veritas (DNV), Lloyd Register (LR), Germanischer Lloyd (GL), and Registro Italiano Navale (RINA)), the International Organization for Standardization (ISO) and the Administrations.

It is expected that future Directives, some already in force such as the ones related to "vessel impact in harbors and waterways", and those referring to vessel impact reduction in the marine environment - Underwater Radiated Noise (some Classification Societies have advanced a Notation Class in this aspect), will end up affecting, in an immediate way, the Contractual Specification Framework.

It is important to remark that in some R&D European Projects within the 7th Framework Program (in which the author is participating) like "SILENV" and "BESST", a future "Green Label" for all types of vessels is being debated.

To help readers to recognize in advance the "technical and economic implications" in vessel design and price, Fig. 1 summarizes Regulations, Polices and Directives in force and the future ones that will appear as Notations Class.

This overview will be done separately by describing the different aspects: **Noise and Vibration on board**, **Noise Radiated to Harbor**, and **Underwater Radiated Noise**, that constitute what the author has called **N&V Full Signature**. For a detailed analysis see Ref [3].

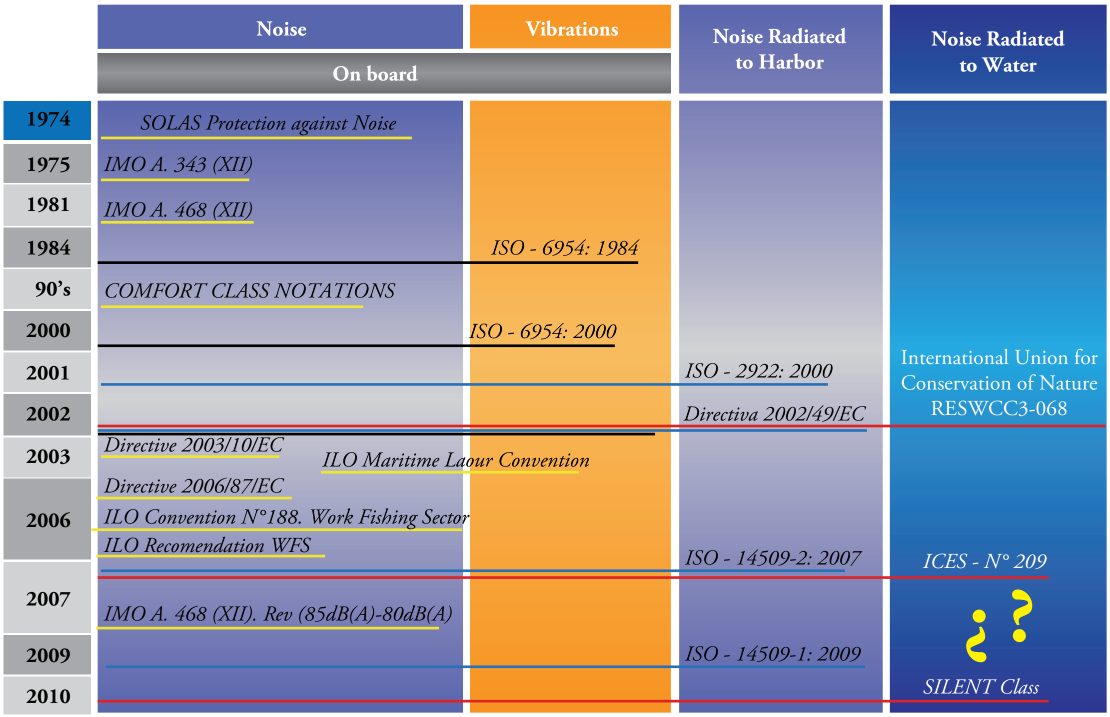
Rules and Regulations referring to Vessel Underwater Radiated Noise

Taking into account that for civilian Shipbuilding, Noise Radiated to Water can be one of the novel aspects, we considered it interesting to extend the chronological aspects of the emergence of new Regulations that will affect it.

The absence of environmental requirements about Underwater Radiated Noise has been a general practice in almost all Contractual Specifications until now, with the only exception of the most modern FRV.

Underwater Radiated problems and their marine environmental impact have only been evaluated in recent years, mainly at the regional level and in those areas where especially vulnerable species live or where more marine mammals and fish are. Glacier Bay (Alaska) deserves special attention; under strict governmental control, vessels are required, as a main requisite, to have the "N&V Full Signature" so as to place them at a proper distance to reduce the impact on the marine life to the minimum.

Fig. 1. N&V Full Signature. The Regulatory Framework



Throughout these years, the emergence of associations to protect marine mammals at international, national, and regional levels has helped in the development of certain rules and treaties that talk about Underwater Radiated Noise and its potential adverse effect on marine life. Among these associations, it is important to highlight the **Internal Union for the Conservation of Nature (IUCN)** whose **RESWC3-.068 resolution** was the first in treating underwater radiated problems, or the **International Council for the Exploration of the Sea (ICES)** whose **ICES-Nª209** [7] **requirement limits**, to a certain extent, the level of Underwater Radiated Noise to a meter from the vessel side and that appears in the most modern fishing research vessel specifications.

The recent **Framework Directive 2008/56/CE** about the strategy of reducing the impact on the marine environment, which represents the first international legal instrument including underwater noise from human source explicitly defined as pollution, along with the most recent publication of an Underwater Radiated Noise Measurement Procedure by the **Acoustical Society of America (ASA-URN)**[8] are the first pillars upon which rules and regulations will set the preliminary steps: technological and design changes that permit reducing or controlling the environmental impact of vessels on marine life.

Classification Societies also deserve special attention; in January 2010, the **"SILENT Class Notation"** [9] of the DNV addressed to all types of vessels was published, including oceanographic research vessels whose limits are the same as those established by the **ICES nª209**, and set different limits for each type of vessel. This Class Notation advances a measurement parameter procedure for underwater radiated noise.

The authors, based on our experience in the dynamic acoustic design, building and delivery of the most modern Spanish Oceanographic research vessels being used in two R&D European projects as "technological reference" on what we should do to minimize the impact of vessels on marine life, want to make clear that both vessels are nowadays working in defining the "technological changes" that will be needed in future vessels to be able to accomplish or come close to having the "Green Label" that will include the limits for each Acoustic

Complete Signature for every kind of vessel: Noise and Vibration on board, Harbor Radiated Noise, and Underwater Radiated Noise.

How will this affect the New Regulatory Framework in the vessel design? Advantages and disadvantages. Threats and Opportunities

In view of this New Regulatory Framework, there are two alternatives, as pointed out in the introduction: to "look the other way" and be limited to a "sub-standard market" or to "answer efficiently" turning what looks like a problem into a business opportunity, this one will give us a favorable position in a more selective market niche, where minimizing the environmental impact of future vessels will be a clear indicator of our difference against cheaper competitors.

Moreover, recent experiences taken from the Spanish Oceanographic Research vessels [10, 11, 12, 13, and 14] that were delivered fulfilling all the current demanding requirements, and based on the confidence given by institutions like the National Industry and the General Secretariat of Marine Affairs and the Spanish Oceanographic Institute let us see a promising and optimistic immediate future.

The following paragraphs will help us understand where we are and where we should go in the design of future vessels, improving certain unattended aspects. In this exam we will explain each part of what we call N&V Full Signature: Noise and Vibration on Board, Noise Radiated to Harbor and Underwater Radiated Noise, showing for each case a summarized "practical guide".

The **"Noise and Vibration Integrated Management"**, in all the detailed aspects in other publications [10, 11, 12, 13, and 14] designed by the author and whose efficiency was proved in strict accomplishment of the most demanding requirements of Oceanographic Research vessels, has been revealed as an "efficient tool" that, when correctly applied, can permit reaching all the new requirements included in the current and new regulations and directives.

The following paragraphs will explain all the recommended "design changes":

- **Vibrations and Noise on board.** Most shipyards already know the implications in the design of the new requirements. Among others, and due to the increasingly demanding trend in the relative limits, we can highlight the following: **1)** Main noise and vibration sources will have to go assembled on elastic mountings correctly calculated, **2)** The propeller has to be designed in a way that will not present any cavitation in any of the operational vessel conditions and that the pressure pulses inducted by it will have to be qualified as very low. Also, cavitation and pressure pulse trials will be stipulated. **3)** In insulation projects (apart from rock wool and drill galvanized sheet for the machinery areas) materials to reduce or minimize "structural noise" transmission such as viscoelastic with tiles will also be considered. The weight incidence of these materials will have to be taken in account. The accurate selection of these materials with the attenuation data required and their assembling could be critical. **4)** Elastic support in the exhaust ducts and insulating elements in the pipes will also have to be considered. **5)** The HVAC system will have to be received "on site" to guarantee that noise levels that HVAC introduces in each compartment are 5 dB(A) under the noise limit of each place. **6)** In the design phase, silencers will have to be installed for the MMEE and AAEE exhaust, as well as for the inlets/outlets of the fans on the decks or open areas. **7)** The compartment will be "floating type" with no rigid connections to the vessel structure. **8)** Providers will be chosen in relation to their "contractual commitment with the shipyard" about the requirements that the specification has requested, as well as with their ability to "provide reliable dynamic-acoustic data" of their supply. The shipyard must know and evaluate the absence of this information that will result in an increase in their expenses. **9)** Vibration Prediction to guarantee that the vessel structure does not show any resonance risk and Noise Prediction to optimize and estimate the insulation correctly will have to be contemplated.

- **Noise radiated to the Harbor.** This recent requirement implies the following specifications: **1)** Special attention will have to be paid to the correct estimation and design of the noiseless acoustics of the inlets/outlets of the fans in the shipside and also to the MMEE and AAEE exhaust. **2)** Special acoustic treatments will have to be plan for the ventilation ducts, whose engines should be assembled on an elastic mounting correctly calculated. **3)** The shipyard will have to ensure the "contractual commitment" of these suppliers with the dynamic-acoustic objectives, and if necessary, will ask for Factory Acceptance Tests. **4)** A calculation tool will have to be used to allow us to make a Prediction of Noise Radiated to the Harbor during the project stage.
- **Underwater Radiated Noise.** Contrary to previous cases, only those national shipyards involved in the building of Oceanographic Vessels know the design implications stemming from the Underwater Radiated Noise requirements. It is clear that the scope of these design modifications to fulfill these requirements will depend on the limits that will be finally decided as "threshold" to avoid affecting marine life. A detailed description of the current strictest requirement could be found in the References [11, 12, and 13]. As a summary, we can highlight the following: **1)** All previous detailed aspects will be applied. **2)** The propulsion will have to be Diesel-Electric with direct current main engines. **3)** Diesel-Generator groups will have to go on double elastic mountings previously calculated and with a contrasted efficiency through a factory acceptance test. **4)** The propeller, apart from fulfilling all previous requirements, will have to be a fixed blade. **5)** All types of propulsion reducers must be avoided. **6)** Special coatings, like viscoelastic with tiles, must be applied in submerged hull areas near the engine rooms. **7)** A special calculation tool that will help us to Predict Underwater Radiated Noise during the project stage must be used, with the intention of introducing any types of changes on time. It must be known that, in general, in case of "non-fulfillmentfulfillment" there is no way back, as corrections tend to be extremely expensive.

After briefly reviewing the necessary "potential design modifications" that will be needed to obtain vessels that comply with the most recent and new-coming Regulations and Directives, the next step will be to inform "in advance" all the professionals involved in the Specifications signing about them. It is of paramount importance that these professionals have a deep and extensive knowledge of the implications that these modifications will have, in order to "enhance their value" while negotiating the vessel's price..

Case Study: Ro-Ro Navantia Vessels for ACCIONA TRANSMEDITERRÁNEA

Description and Main Particulars

At the end of March and during mid August 2010, **NAVANTIA-Factoría de Puerto Real** delivered the RO-RO vessels **"José María Entrecanales"** (C-509) and **"Super-Fast Baleares"** (C-510) to the Spanish company **ACCIONA TRANSMEDITERRÁNEA**. Both last generation units constitute the biggest freighters in the Spanish market. They have been designed to have two weekly rotations in routes between 700 and 800 nautical miles or, alternatively, a weekly rotation in routes of 1.500 nautical miles. The main characteristics of these vessels and their main machinery are collected in Fig. 2.

Finally, as important noise sources in these types of vessels, we can highlight the ventilation of the hold and the engine room. Both vessels have 58 ventilation units, some of them with a capacity of up to 120,000 m3/h.

Basic Objectives of the Project. Noise and Vibration Specifications. ISO Standard 2992/2000

In the contractual specification signed by the shipyard and the ship owner, a "Noise and

Fig. 2. Main characteristics of the vessels and their main machinery

Main Particulars	
Total Lenght	209,00 m.
Lenght b. PP	190,00 m.
Breadth	26,5 m.
Depth to M. Deck	9,60 m.
Design Draught	7,00 m.
Molded Draught	7,10 m.
Dead Weight	9,325 t.
Potencia Propulsora	4x10,800 kW a 500 RPM
Speed	26 Knots
Autonomía	
Capacidad de Carga: • N° of modules 14,3 m. • N° Containers "mafi" • N° Cars at Deck	 187 23 100
Crew	40 Persons
Classification	BUREAU VERITAS.

Main Particulars of Main Machinery	
Main Diesel Engines	
Mark	MAN DIESEL & TURBO
Model	9L 48-60 B.
Nominal Power	10,800 kW
Nominal Speed	500 RPM
Number of Cylinders	9
N° of stroke	4T
N° de Units	4
Gear Box	
Mark	RENK
Reduction Rate	3,324:1
N° de Units	2
Propeller	
Diameter	5,200 mm
Number of Blades	4
Pitch	Variable
Nominal Speed	150 RPM

Vibration Level" specific section is highlighted and because of its importance for this project, it is shown in these different sections: **1) "A Noise Prediction will be performed in different areas of the vessels". 2) "The acceptable Noise levels will be those established by the IMO in the A.468 (XII) Resolution [4]". 3) "A noise level measurement will be done in the places and conditions established by the IMO to prove that they do not exceed the limits". 4) "Vibration levels in the cabin, common areas, and public areas for crew and passengers will not be in the zone of "values likely to adverse comments", established by the ISO Standard 6954/2000 [5]". 5)"Exterior noise levels under 80 dB (A), measured according to ISO 2922/2000 [6] with the vessel in operational conditions in the harbor". 6) "A vibration measurement will be carried out to check that the vessels fulfill the previously mentioned rule"**.

Noise and Vibration requirements were set thus:

Vibrations in compliance with **ISO Standard 6954/2000** [5]. Noise corresponds to **IMO A.468 (XII) Regulation** [4].

The following comments and observations are taken from a Noise and Vibration section included by the ship owner in the Contractual Specification:

- It is the first time that a fulfillmentfulfillment requirement about noise level **(80 dB (A))** with the vessel in operational conditions in the harbor appears in the Contractual Specification. This is considered a clear example of foresight of the evolution in Environmental Regulations from the Ship owner's side.
- The ship owners "show a high sensitivity" to the working conditions of their employees (the crew) and the clients (the passengers), demanding the fulfillment of noise and vibration limits set by current rules **IMO A.468 (XII) Regulation** [4] and **ISO Standard 6954/2000** [5].
- Finally, and to be sure that all the appropriate measures will be considered by the shipyard, the ship owner demands compulsory **"Prediction Studies"**.

Normally, the first position to take is to continue **"doing things as they were done for the last years"**, without taking any preventive measure that can guarantee the compliance with the rules. This position, even when believed to "reduce cost", only leads to the opposite effect: several penalties, last minute corrections with fines for late delivery, and excessive costs in the corrections, as well as vessels already finished and it is technically and economically impossible to be modified.

In the past, when these specifications where ambiguously defined, it was more frequent to "toss the coin" and wait for the vessel to vibrate or not, it could be normal at that time given the state-of-the-art in these matters. Nowadays, as it can be proved, it makes no sense and has no technical or economic justification. In fact, in the case study that will be presented in this work, it will be clear that not taking preventive measures regarding noise radiated to the harbor, could have led to a brand new vessel with limitations in the loading and unloading operations in certain Spanish and European harbors, and also to possible fines and complaints.

Before, with other less strict specifications on noise and vibration it was not necessary to have profound knowledge in this area and it was possible to avoid complications in the compliance. But currently, it will be increasingly obvious that those responsible for signing the specifications will need to have some basic knowledge or experience on this matter, or that they will receive professional advice to quantify the real economic incidence in the final price.

Going back to our case, if the studies required by the shipyard had not been done, the vessels involved in this project would not have accomplished the contractual specification, mainly in relation to **Noise Radiated to the harbor**.

The requirement from the ship owner to fulfill the **ISO 2922 Standard "Measurement of airborne sound emitted by vessels on inland waterways and harbors"** [6], requiring a contractual limit of **80 dB (A)** at 25 meters from the vessel. The rule has as a main goal of avoiding complaints and fines when the vessel ties up near densely populated areas.

The shipyard (**NAVANTIA-Puerto Real**) and the engineering company **(SENER)**, looking at the recommendations made by the authors of this material, addressed this requisite even more realistically than required by the specification, by asking for noise radiated prediction studies that allowed satisfying not only the ship owner's requirements, but also to have an almost unique reference of a **"Silent Vessel"** in the harbor.

Shipyard response: What has been done? How has it been done?

General information

First, the ship owner **ACCIONA-TRANSMEDITERRÁNEA**, based on their previous experience and aware of the importance of fulfilling noise and vibration aspects, required the use of Noise and Vibration Simulation and Prediction techniques as a guarantee to meet those goals.

Meanwhile, the shipyard, **NAVANTIA-Puerto Real**, with vast experience in the noise and vibration field, with civilian and military cargo vessels, in an attempt to meet all the strict requirements, showed from the beginning special attention to covering all the ship owner's requests; knowing that to fulfill the demanding specifications it was necessary to understand the principle that **"Dynamic and acoustic design of the vessel is most important"** in this project.

Consequently, **NAVANTIA-Puerto Real** required **SENER** and the assistance of a specialized company (**TSI**), which was in charge of **Noise and Vibration Integrated Management** and added the **"design principle"** to all its processes.

What has been done? Basic principles

Vessels are elastic systems that when under periodic forces, coming from different sources, are **"subject to vibrations"**. The vibration level obtained in the system (vessel) depends, mainly, on three parameters: **1)** The **Intensity** or magnitude of the excitation forces. **2)** The **Rigidity** of the structure. **3)** The dynamic **Amplification** at different frequencies due to local and global resonance phenomena.

Thereby, the **possible actions** to keep **vibration levels** under the **pre-set limits** are the following: **A)** Minimize the excitation forces of the system. **B)** Avoid flexible structures from a dynamic point of view. **C)** Avoid resonance phenomena by coincidence of structural frequencies and excitation frequencies.

Similarly, and from an acoustic point of view, the vessel has built-in **Sonorous Focus**: Main engine and Auxiliary ones, Propeller, Hydraulic Systems, HVAC, etc. that are **airborne** and **structure borne** noise generators, noise transmitted or spread along the structure of the vessel (**Means**) that reaches the different premises (**Receivers**), as well as radiated to the water.

Likewise, the **possible actions** to maintain noise levels under the **pre-set limits** are the following: **1) Minimize** the resonant and vibration power from different resonant focuses. **2) Reduce** or diminish their transmission to the medium. **3) Duly isolate** the receptors.

How has it been done? Procedures

If we review the **possible actions** to control noise and vibrations levels in the vessel, we confirm that they can be grouped into two modules:

- A **first module**, comprising all those **actions aimed at minimizing the magnitude of the excitations** (noise and vibration) generated by different sources and focus, which are completely beyond the shipyard's duties and competence, and which correspond to the **different suppliers' scopes**.
- A **second module** that includes all the possible actions related to vessel structure, absence of resonance phenomena, separation and isolation of receptors and focus, correct assemblies and isolation are within the aspects of the Project, Structure and General Disposition, Building and Assembly, and in consequence, embraces to the **shipyard's scope**.

The **first module** within the **Noise and Vibration Integrated Management** and as a control mechanism should incorporate **"dynamics and acoustics specific requirements"** in the purchase specifications of the different supplies, as well as **Reception and Verification Procedures**.

In the second module of possible actions, under the direct responsibility of the shipyard, the previously mentioned principle **"Dynamics and Acoustics Vessel Design is most important"** is assumed from the beginning of the project. This implies the following points: **A)** Name an internal and external coordinator that will supervise and coordinate, from a dynamic-acoustic point of view, all the processes and supplies. **B)** The project must consider the selection of shapes and wakes that minimize the risk of propeller cavitation, as well as careful maintenance of the structural continuities. **C)** The General Disposition must guarantee an optimum separation between focus and receptors with high acoustic requirement, along with minimum isolation levels. **D)** Assemblies must minimize the "building" of noise and vibration transmission bridges to avoid connecting rigidly moveable parts of the equipment to hard points of the vessel structure.

To supplement, and for the purpose of minimizing resonance risk and optimizing the acoustic behavior of the vessel, the **Noise and Vibration Integrated Management** considers carrying out a **Dynamic Acoustic Design** of the vessel that will be accomplished in the following sections: **1)** Vibration Prediction. **2)** Noise Prediction. **3)** Radiated Noise Prediction.

Experience shows and the case study presented in this document reinforces this, that the proper introduction of this **Noise and Vibration Integrated Management** methodology [11, 12, 13] yields, among others, the following advantages: **V1)** Ensure that all the preventive measures were taken in the different processes and in the right moments. **V2)** Incorporate this methodology to future manufacturing standards. **V3)** Fulfill the specification, and finally, "Client-Shipyard" satisfaction at the lowest possible cost.

Practical application of the "NOISE AND VIBRATION INTEGRATED MANAGEMENT" in the vessels: "JOSÉ MARÍA ENTRECANALES" and "SUPER-FAST BALEARES".-

General Scope

The experience based on the excellent results obtained in the **"Silent Vessels"**: Oceanographic Vessels **"Miguel Oliver"**, **"Sarmiento de Gamboa"**, and the Fishing Research Vessel **"Emma Bardan"**, permits confirming that compliance of these strict requirements demands a complete development of the methodology of **Total Noise and Vibration Management** that the authors are applying and that includes, in a minimum range, the development of the principle and procedure previously exposed.

With this **"first activity level"**, it sought for the shipyard to develop and exert "control" over those aspects that, as previously described, are in the scope of the suppliers. The intention with this is to achieve what is called **"contractual sensitivity"** of the suppliers towards the dynamic and acoustic objectives of the project. Its **"no-application"**, leaves the shipyard, in many occasions, "with tight hands" when it comes to finding more economic and technically efficient solutions or countermeasures.

The **"second level"** of activities considers all those aspects in direct competence with the shipyard, as it is the supplying of a structure with an appropriate dynamic design: without resonance and enough acoustic isolation to guarantee the minimum requirements. In this section, all the simulation techniques are integrated, like: **A)** Vibration Prediction through Finite Element Method. **B)** Noise level Prediction in the vessel locals through SEA Method. **C)** Noise Radiated to Harbor prediction, when required. **D)** Underwater Radiated Noise Prediction, when required.

In the case study we are working on, the development of the **Noise and Vibration Integrated Management** scope has been, as indicated, "partially" focusing only and exclusively on the application of **"Simulation Techniques"** for those aspects required in the specification: Vibrations, Noise and Noise Radiated to Harbor.

Prediction through Finite Element Method in the building of NAVANTIA-Puerto Real C-509 and C-510

A finite-element mathematical model of calculation (FEM) was applied, seeking to avoid dynamic amplification phenomena due to possible **"Resonance Phenomena"** in the vessel structure, to identify own frequencies and avoid their coincidence with the main excitation sources of the vessel: Forces and Moments of Main Engines excitation and Forces coming from Pressure Pulses inducted by the propeller on the sternpost.

The application, to this dynamic model of the vessel structure, of the different forces of the excitation source: Main Engines and Propellers, will help us to obtain the "Expected Vibration Levels" in the different areas throughout the vessel structure. From the comparison between these "Expected Vibration Levels" with the limits required in the **ISO Standard 6954/2000** [5] demanded in the specification, decisions will be taken that will allow us to validate the structure from a dynamic behavior point of view or introduce those structural modifications that guarantee this compliance within the required limits. In Fig. 3 we can see a summary of the methodology applied.

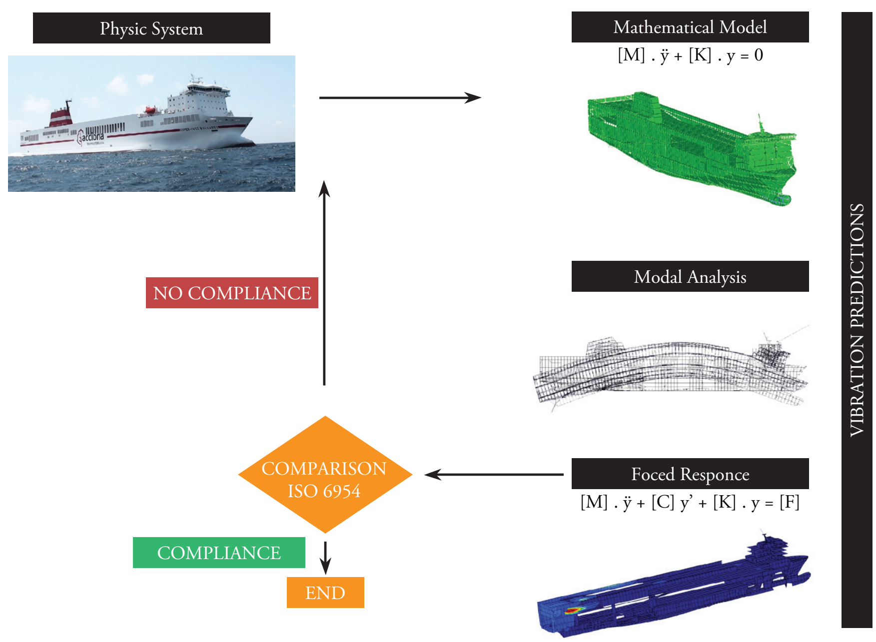
Description of the Mathematical calculation model.

To represent the dynamic characteristics (mass and stiffness) of the structure, two-dimensional elements like plate (shell) were mainly applied, capable of admitting distortions in its plane and perpendicular to this, using one-dimensional elements (beam) for the primary structure and struts. Equipment with weight over 1000 kg has been considered as point masses distributed in the area where beams are supported, with the exception of the main engine and the reduction gear that has been modeled with two-dimensional elements. To perform the calculation, ballast and consumer tank filling were taken into account. In Fig. 4 the mathematical model used can be seen.

Calculation Fulfilled.

On the mathematical model, two types of calculations were performed, as described in the following lines:

Fig. 3. Methodology of the Vibration Prediction



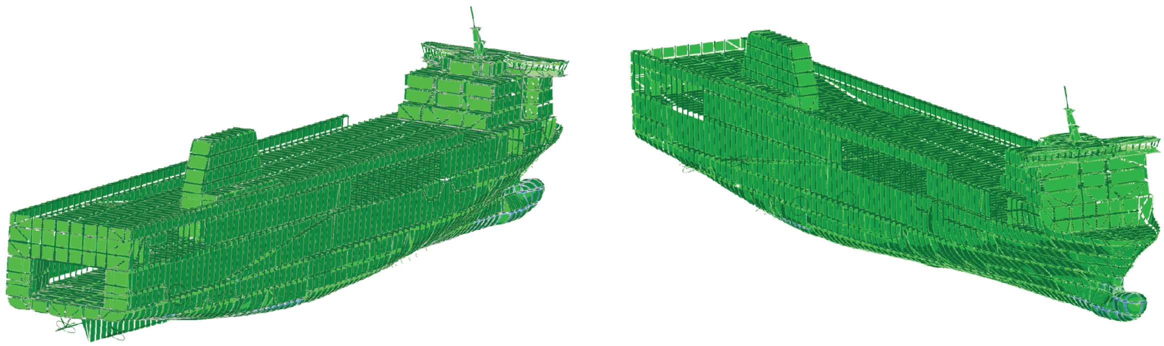
Modal Calculation: Through this calculation, the eigenfrequencies or resonance frequencies of the vessels and their vibration mode shapes were obtained. The coincidence between eigenfrequencies and excitation frequencies (propellers and propelling engines) can produce a phenomenon called resonance and then high levels of vibration could be produced. This type of calculation is an essential requisite to be able to make the forced response calculation or to predict vibration levels.

Forced response. Vibration levels prediction: This calculation includes the characteristics of the vessel through the modal calculation and the characteristics of the excitation sources (amplitude and frequency) to obtain the expected vibration levels in the vessel structure.

Results obtained.

As previously pointed out, the relative location

Fig. 4. Finite-Element Mathematical Model



of these eigenfrequencies in relation to excitation frequencies mainly inducted by the main engines and the propeller, allows a first evaluation of "resonance risk" at local and global levels.

In Figs. 5 and 6, vibration modes and shapes associated with the first three modes or eigenfrequencies of the ship-beam obtained, were collected.

For readers who are not experts in this matter, the view of these vibration ways help us understand, in didactic manner, why they are called "Vibration frequencies and shapes of the ship-beam".
Because of the high level of discretization used in which almost all elements were represented, the modal calculation allows us to obtain a high level of local eigenfrequencies, corresponding to deck plates, bulkheads, etc., whose graphical and numerical representation would be thorny. In this case, it was preferred to represent the following step of **"Forced Response"** that will permit, in a more illustrative way, identifying those structural areas with more problems or risks of **"Local resonance"**.

For the **"Forced Response"** calculation, the main excitation forces used were: pressure pulses inducted by the propeller in the sternpost to the excitation frequencies **1xBPF** (Blade Pass Frequency) and **2xBPF**, and the forces and free moments coming from the main engines to the excitation sources **1xRPM**, **2xRPM** and **4.5 RPM**, as harmonic or more significant orders. Auxiliary engines, not considered because of their isolation by elastic suspension and the bow propeller, due to its study can be found within an analysis of noise presented in this work.

Fig. 5. First Vertical Bending Mode Shape. 1.78 Hz

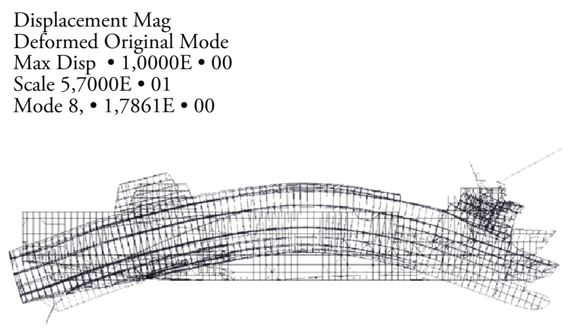
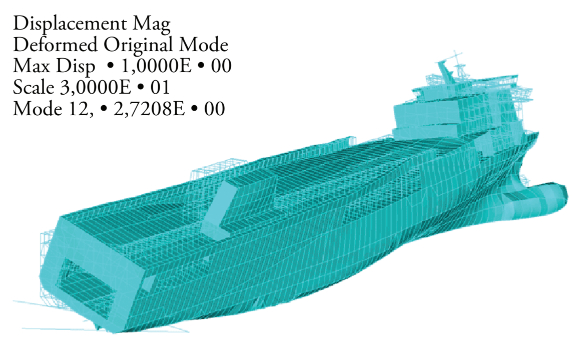


Fig. 6. First Torsional Mode Shape. 2.72 Hz



The excitation amplitudes previously mentioned, those corresponding to the propellers and the engines, appear at nominal regime (150 rpm propeller speed and 500 rpm propelling engine speed). For other working regimes, the excitations have lowered with hydrodynamic laws. It is important to highlight that vibration predictions do not cover the working conditions of the propeller at regimes under nominal, in which propeller cavitation is produced, like in harbor maneuvers and working with the machine back (crash stop).

The application of these excitation forces, in the most conservative case that both are acting in phase, the mathematical model has helped us to obtain, through colored maps, the distribution of the "expected vibration levels" in the different locations of the vessel structure. In Fig. 7, different colored maps are collected to show the different main excitations.

Noise Prediction through SEA Method

Brief introduction to SEA Method.
To make a noise prediction it is necessary to consider the acoustic excitations and their transmission paths, this means working in high frequency. The **SEA Method (Statistical Energy Analysis)** offers a way to alternatively model **FEM** and **BEM**, and to represent the vibratory state of a system. The model represents the means behavior of a group of similar systems and it also includes an uncertainty factor in the model. The vibratory state is expressed in terms of vibratory energy of individual components. The application of these excitations is expressed in terms of power. And the relation between the excitations and the energy of the elements is expressed in terms of energy flow.

General description of Noise Prediction.
In this chapter the intention is to describe the general methodology for noise level prediction in different locals of the vessel due to the focus of existing noise, using **SEA** method. The first step to define a noise model is to create the topology of the vessel. Once created, the second step is to create the analysis model. In the analysis model, information about the thickness of the plates, space between stiffeners, noise sources definition, local receptor definition and local transmitting and acoustic treatment applied information must be included. With the analysis model created, we can proceed to solve it and as a result expected noise levels in the selected compartments are obtained.

The comparison of theses expected levels with the established limits in the technical specification, will take us either to finish the process or, in the contrary, through a repetitive process to simulate special systems of isolation aimed at reducing noise levels in those compartments which do not accomplish the Specifications. In Fig. 8 a graphic Flow Diagram that corresponds to this methodology is described.

Fig. 7a. Expected levels in the structure for the main excitations (1xBPF)

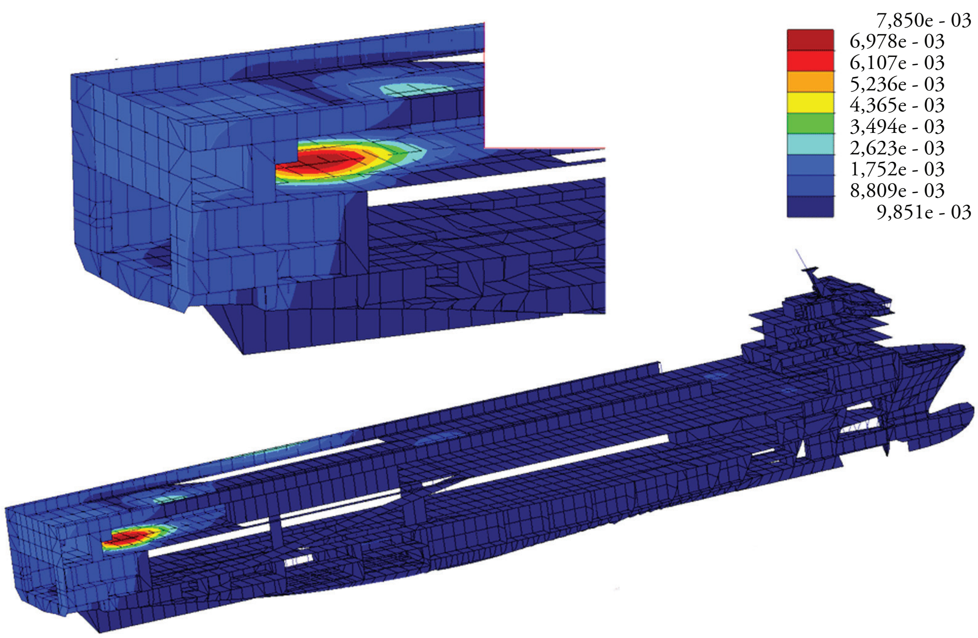


Fig. 7b. Expected levels in the structure for the main excitations (4,5xRPM)

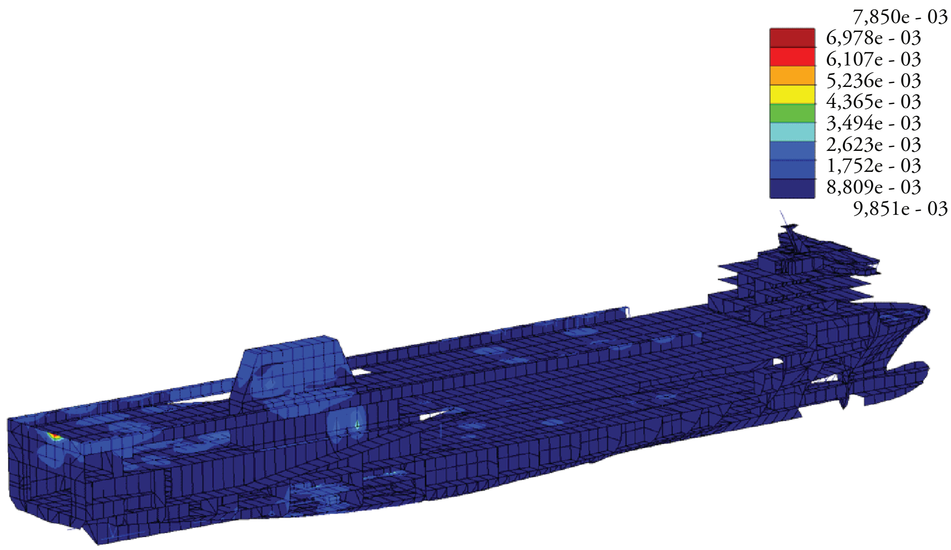
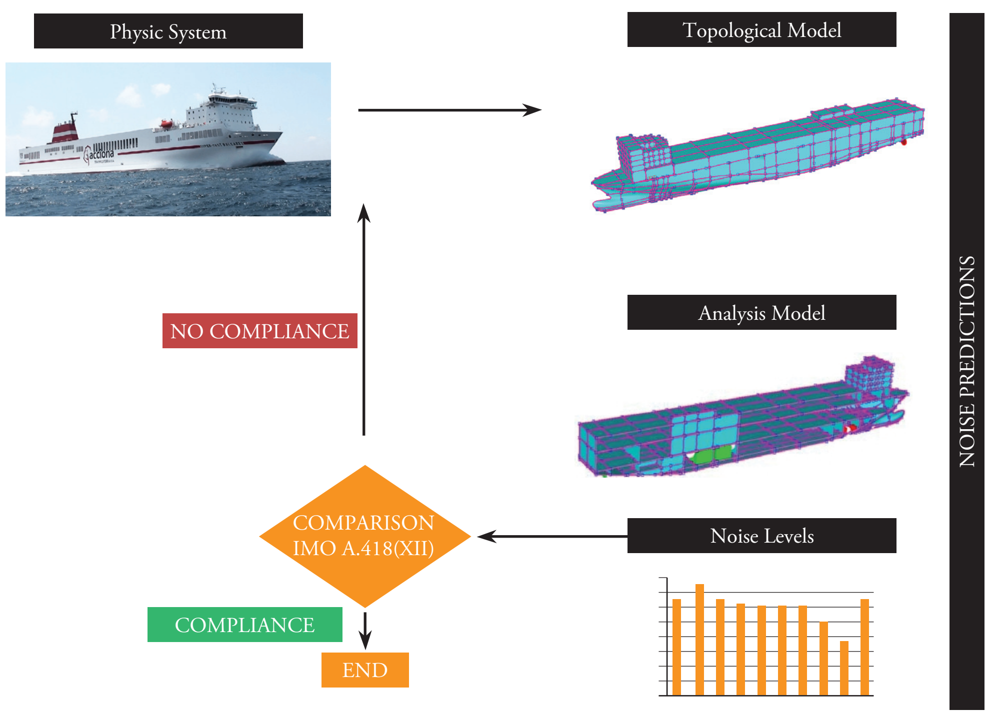


Fig. 8. Methodology of the Noise Prediction



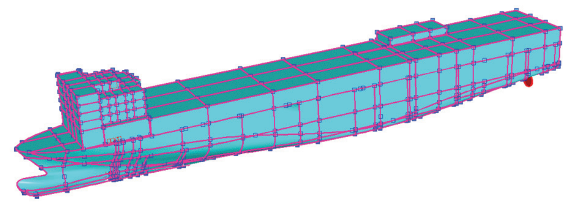
Mathematical Model Description.

SEA method includes two types of existing structure borne noise, the one transmitted by a noise source through the structure, and the one generated in the structure due to airborne noise. To calculate noise level, the following parameters have been taken in account:

1) The thickness of the plates and the distance between the reinforcement. **2)** Air noise level and structural noise level of the different equipment. **3)** Isolation drawings in bulkheads and roofs, pavement and sub-pavement. **4)** Plan of the General Disposition of the vessel and situation of focus and locals.

The noise sources, among others, that have been considered to predict noise in the C-509 and C-510 are the following ones: propellers, main engines, gearboxes, auxiliary engines, thrusters, compressors, harbour generator, purifiers, steering gear, HVAC units, fans engine room, garages and technical spaces. In Fig. 9 we can see the Acoustic Model used.

Fig. 9. Acoustic Model of the RO-RO's C-509/510



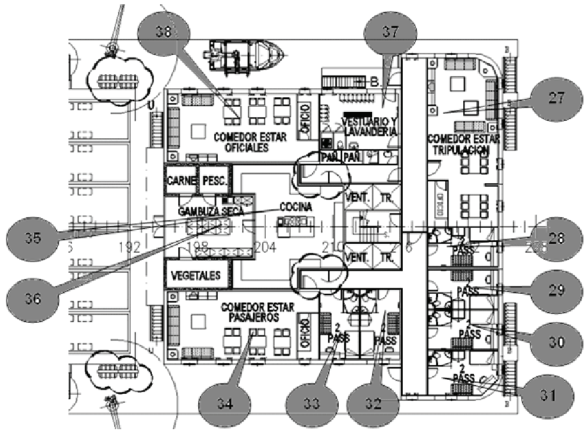
Noise Results obtained with the original Model. Analysis and Acoustic reinforcement.
Original Model Results/ Modified Model.
Noise level predictions in the locals of the vessel have been done considering the working conditions in **Free Sailing at 90% MCR**. Additionally, a prediction of noise level has been done for the **Load/Unload** condition.

In the following table Fig. 10 shows, for one representative deck, the equivalent pressure levels in dB (A) obtained in each local through simulation in both analysed conditions. Meanwhile, Comfort level limits established in each local are shown, in relation to the Specification, as well as the corresponding prediction evaluation.

UNACCEPTABLE levels are those that **exceed the specified limit, SEVERE** levels are those at **less than 2 dB (A) below the limited level**, and **ACCEPTABLE** are those at **2dB (A) below the specified limit**. Additionally, we indicated if this evaluation refers to Free Saling or Load/Unload condition. In Fig. 11 found are the distribution of the expected noise level in C-509/510 with the Original Insulation and the operational conditions tested: **Free Sailing 90% MCR and Load/Unload** and the corresponding **Modified Acoustic Model**.

Fig. 10. Noise Level Prediction in a Representative Deck

Deck 7 - Forw-Aft- Sound Pressure Levels Expected				
Space	**N.L.**	**L/UNL**	**Limit**	**Assesment**
23. Chimney	84	80	110	ACCEPTABLE
24. Port Generator	81	77	75	ACCEPTABLE
25. Chimney	84	80	110	ACCEPTABLE
26. Store	80	64	90	ACCEPTABLE
27. Comedor Tripulación	59	64	65	*SEVERE*
28. Passenger Cabin	61	67	60	OVER LIMITS
29. Passenger Cabin	61	67	60	OVER LIMITS
30. Passenger Cabin	61	67	60	OVER LIMITS
31. Passenger Cabin	61	67	60	OVER LIMITS
32. Passenger Cabin	62	68	60	OVER LIMITS
33. Passenger Cabin	62	68	60	OVER LIMITS
34. Comedor pasajeros	62	68	65	OVER LIMITS
35. Kitchen	57	62	75	ACCEPTABLE
36. Gambuza seca	57	62	75	ACCEPTABLE
37. Clothing and Laundry	63	69	75	ACCEPTABLE
38. Officer's mess	62	68	65	OVER LIMITS



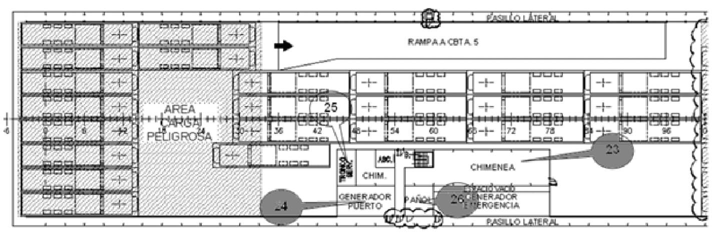


Fig. 11a. C-509/510. Noise Level Distribution. Original Insulation

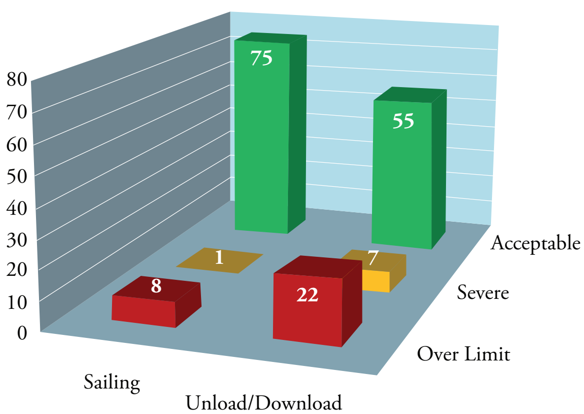
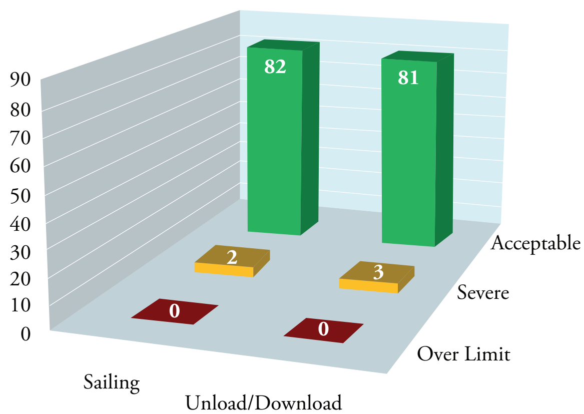


Fig. 11b. C-509/510. Noise Level Distribution. Modified Insulation



Noise Radiated to Harbour Prediction. Answer to the new requirements

Introduction.
The appearance of a **"totally new requirement"** in the Specification of **C-509/510** of **NAVANTIA-Puerto Real** from **ACCIONA TRANSMEDITERRÁNEA**, that the **"Exterior noise level should be under 80 dB(A), measured according to ISO 2922/2000** [6] with the vessel in operational harbour condition", has constituted a "novelty".

The reasons for this "new requirement" are two: one is the **Operational**, that answers the need of the Ship-owner to avoid complaints and fines. The second is the **Vision and Sensitivity** from **ACCIONA TRANSMEDITERRÁNEA** in accomplishing the Community Directives related to Evaluation and Management of Ambient Noise in the Harbours, **Directive 2002/49/CE** [2] specifically.

In this point we need to ask ourselves **"What did the shipyard do in view of these new requirements?", "Did the shipyard know about the technical and economic incidence of this "added value" that the vessel required?"**.

Calculation Method applied.

The prediction of the noise generated by the vessel to the harbour has been done counting as a main noise sources the inlets/outlets of the ventilation system that the vessel can have in use during the stay and operations in the harbour.

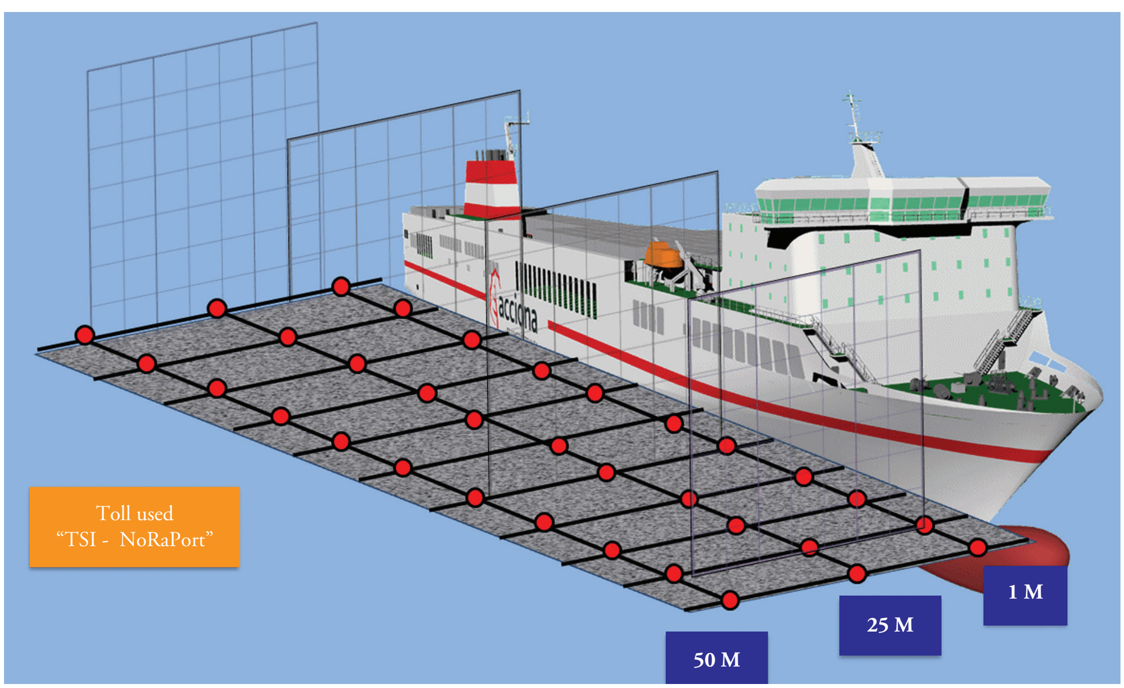
Those inlets/outlets of ventilations had been considered as hemispherical noise sources, in a way that each one generates a sound field of spherical waves. The levels of acoustic power, from each inlets/outlets, have been calculated considering the power and noise pressure of each fan, the ducts dimension and the fan chamber, and its acoustic insulation in case of having it.

As a consequence the accuracy of the obtained results has been constrained by the precision of the data given by the supplier. As a result, with the experience of the authors, this data had to be experimentally proved through factory acceptance tests. In this vessel, the main noise sources of Harbour Radiated Noise are integrated by 58 Ventilation fans from the garages and machinery rooms.

The exhaustion of the main engines and the auxiliary ones have not been considered in this analysis, as the acoustic treatment of this noise source is constrained by the fulfillment of the noise limit in the exterior decks.

With these noise sources characterized, and using the Calculation Model described in Fig. 12 and with the tool developed with **TSI**, called **"NoRaPort"**, we proceeded to estimate, for the different configurations, noise level at the different distances of the vessel. Not only in the quay but also in the main sections of it, where most of the noise sources to the harbour were found. The comparison of these "expected noise levels" at different distances and mainly at 25m of each side of the vessel, and t**he comparison of the Specified limit of** 80 dB(A), allowed us to optimize the acoustic design of the different ventilation systems.

Fig. 12. Noise Radiated to the Harbour Model



Acoustic ORIGINAL Design of Fans. Obtained Results.

The corrections experimentally obtained through FAT tests (Factory Acceptance Tests), as security margins, it was proceeded to do the first prediction of Noise Radiated to Harbour calculation with the **Original Acoustic Design of Fans and Silencers**. In Fig.13 it is represented the distribution of the resonant weighted pressure level (A), at quay level for port and starboard sides. The represented coloured map was obtained considering 3 distances of calculation, from each of the vessel sides, **1 meter, 25 meters and 50 meters**. With the arrows graphs we represented the gradient of pressure levels from the quay side according to the obtained results.

The analysis of the previously exposed results shows that the expected pressure level **EXCEEDS in +11 dB (A)** the contractual required levels.

For the optional condition analysed (at 1m from the side) out of the Specification, in the same operational conditions as the previous case vessel, the expected noise pressure levels resultant **EXCEEDS in +18 dB(A)** the level of **80 dB(A) at 1 m** from the side.

Acoustic MODIFIED Design of fans. Obtained Results.

Based on the deficient results obtained in the prediction of the noise radiated to the harbour with the **Original Acoustic Fan Design**, the

Fig. 13. Original Model. Noise Radiated to the Port. Starboard and Port Side

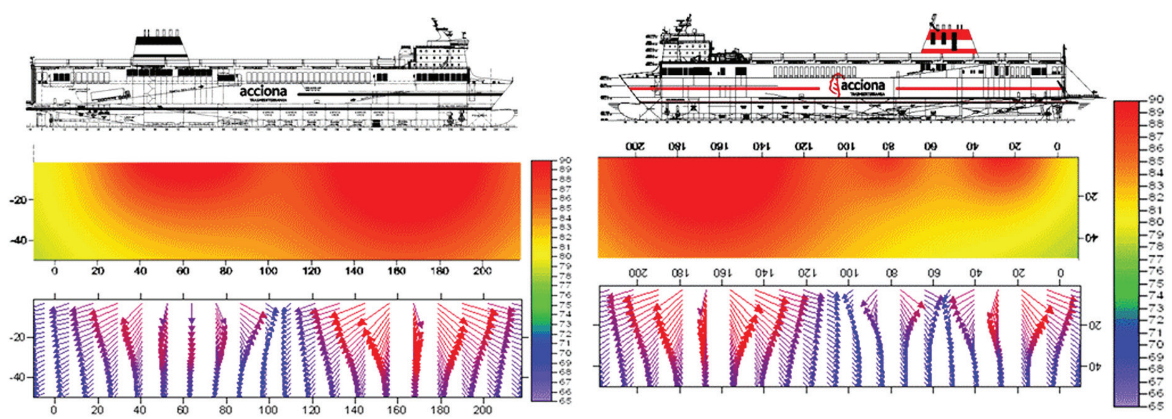
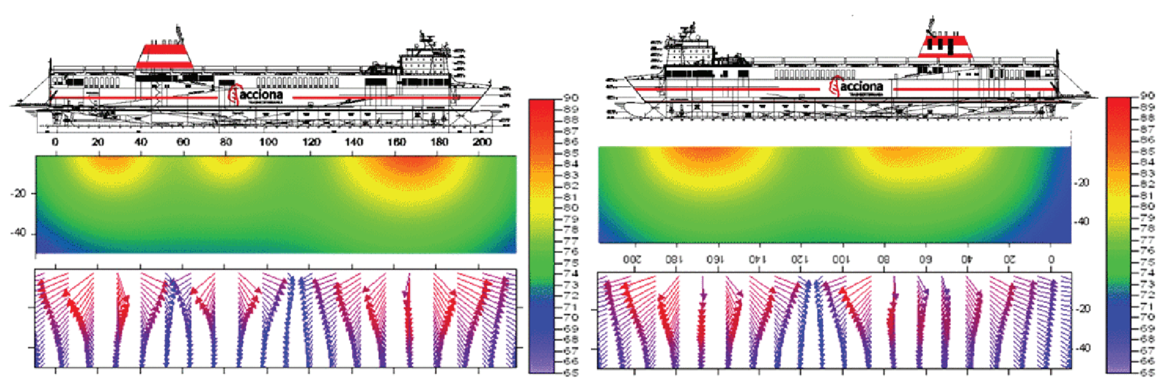


Fig. 14. Optimization at 25m. Noise Radiated to Port Distribution. Starboard and Port Side



company responsible for the calculation of noise and vibration and exterior noise prediction knowing the needs of the ship-owner and of the Regulations, not mentioned in the Specification but currently in force, recommended the Engineering and the shipyard to do two levels of actions on the silencers: a **First Level** of actions that we will call **Optimization at 25m** and a **Second Level** of action called **Optimization at 1m**. In Fig. 14 are shown the results obtained in the **Optimization at 25m**.

As it can be seen in the analysis of them, with the first action, level noise radiated to harbour by the **C-509/510 fulfilled**, for both sides of the vessel, with the 80 dB (A) limits required in the Specification. The application of the recommendations of the **Second Level** corresponding to **Optimization at 1 m** of the side, has conducted to the results collected in Fig. 15.

As it can be seen in the analysis of Fig. 16 with the **Second Level of action**, noise radiated to harbour by **C-509/510** fulfilled, for both sides of the vessel, with the 80 dB(A) limits required. As this option: **Optimization at 1 m** meant an **"indisputable improvement"** of the vessel features, as it implied not only guaranteeing the fulfillment of the Noise and Vibration Specifications but also with the adaptations of it to the in force more recent Directives, its application was constrained by the decision of **NAVANTIA-Puerto Real**.

Sea Test in NAVANTIA- Puerto Real C-509/510: Correlation Model/ Tests

Aimed at verifying the fulfillment of the Contractual Specification in the noise and vibration sections, before delivering each of the **C-509** and **C-510**, **TSI** developed (as the consulting company

Fig. 15. Optimization at 25m. Noise Radiated to Port Distribution. Starboard and Port Side

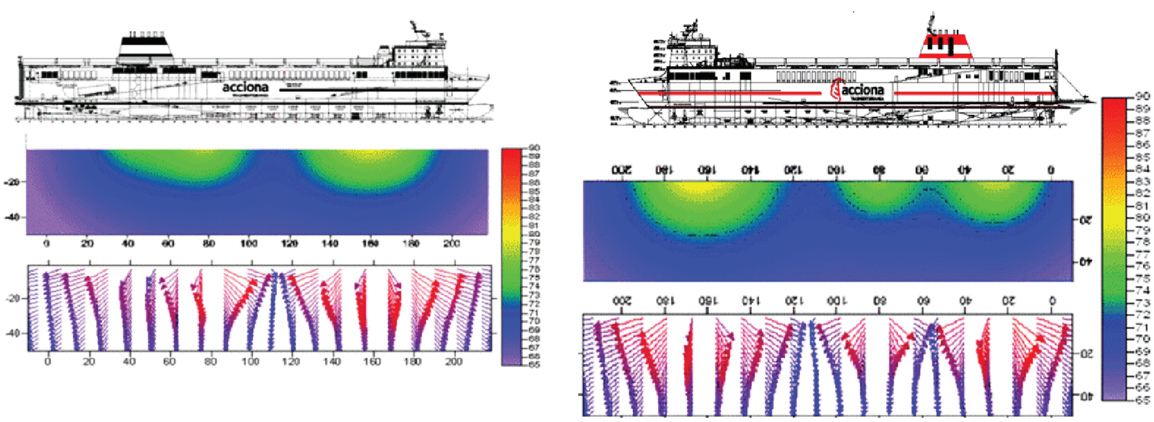


Fig. 16a. Optimization at 1 m. Distribution of the Pressure Levels at 1 and 25 m length

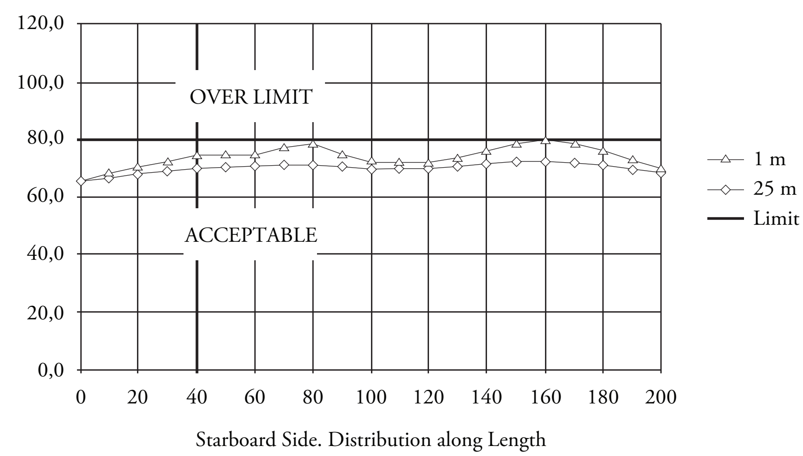
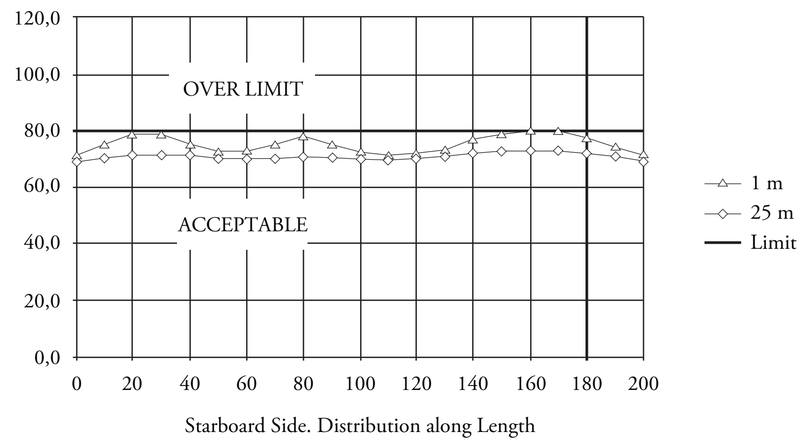


Fig. 16b. Optimization at 1 m. Distribution of the Pressure Levels at 1 and 25 m length



in charge of the Noise and Vibration Integrated Management), with the previous elaboration of the corresponding protocols accepted and approved by the ship-owner and the shipyard, a program of sea trials that included structural and local noise and vibrations measurement in the main equipment.

The experimental results obtained in this program of Official Tests, which will be summarized in the following sections, will help us to evaluate the goodness and efficiency of the noise and vibration predictive calculations applied.

Vibrations Results

In Fig. 17 there is a summary of the vibration levels obtained in the different areas: machines and working spaces, public spaces and crew & passenger cabins, of the Ro-Ro's vessels **"José María Entrecanales"** and **"Super-Fast Baleares"**, measured during the sea trials when delivery. In those figures and for each type of space, we included the required limits in relation to **ISO Standard 6954/2000** [5] that its fulfillment was included in the Specification.

From the experimental data examination of vibration levels obtained in the Official Tests of the vessels **"José María Entrecanales"** and **"Super-Fast Baleares"** we can highlight the following ones:

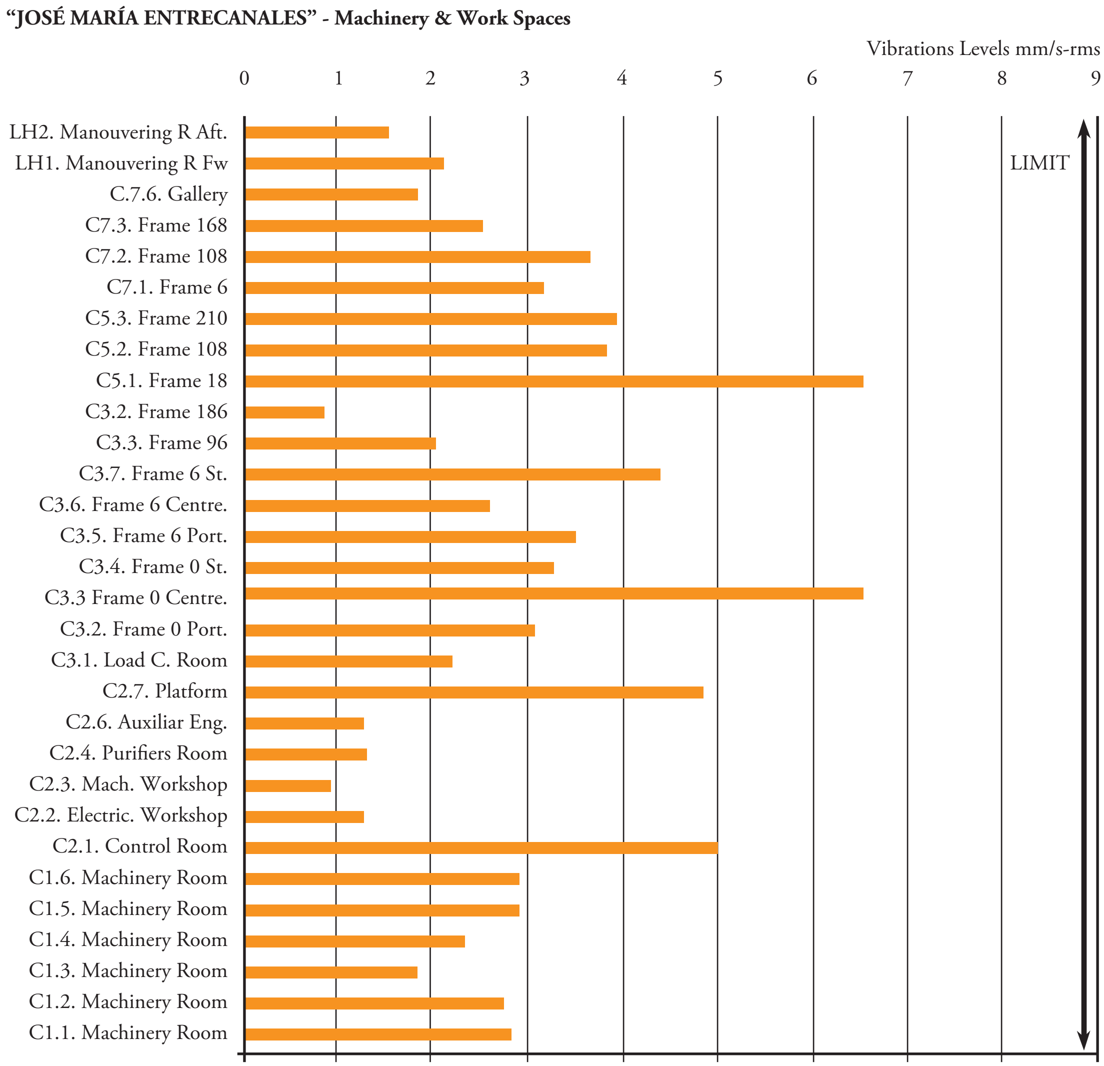
- In both vessels, vibration levels obtained in the different localization are well below the required limits in the **ISO Standard 6454/2000** [5].
- In both vessels the **IMPROVEMENTS** (deviation respect the limits) obtained oscillate between 62% and 71% **below the contractual limits**.
- In a general way, vibration levels obtained in both vesels during the sea trials allow us to confirm that the **"Dynamic design"** in both constructions delivered by **NAVANTIA-Puerto Real**, designed by **SENER** and calculated by the authors, fulfilled satisfactorily the Specification requirements (**ISO 6954/2000** [5]) even being able to opt for a **Comfort Class 2**.

Noise Results

In Fig. 18 there is a summary of noise levels in different areas: machines and working spaces, public spaces and crew & passenger cabins, of the Ro-Ro's vessels **"José María Entrecanales"** and **"Super-Fast Baleares"**, measured during the official tests when delivery. In those figures and for each type of space, we included the required limits in relation to **IMO A. 468(XII) Regulation** [4] that its fulfillment was included in the Specification.

From the experimental data examination, of noise levels obtained in the sea trials of the vessels **"José María Entrecanales"** and **"Super-Fast Baleares"**,

Fig. 17. Vibration Levels obtained at different Locations



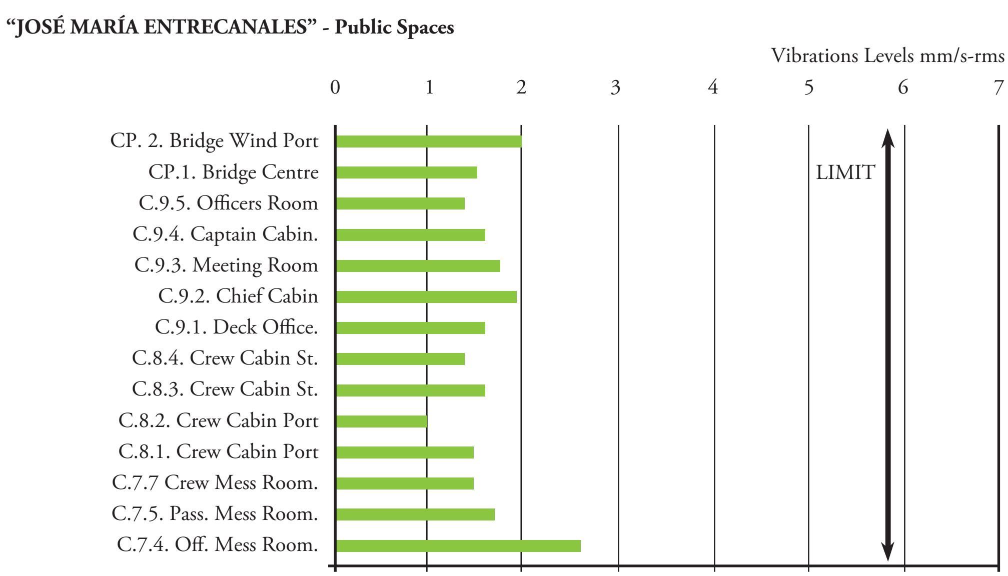
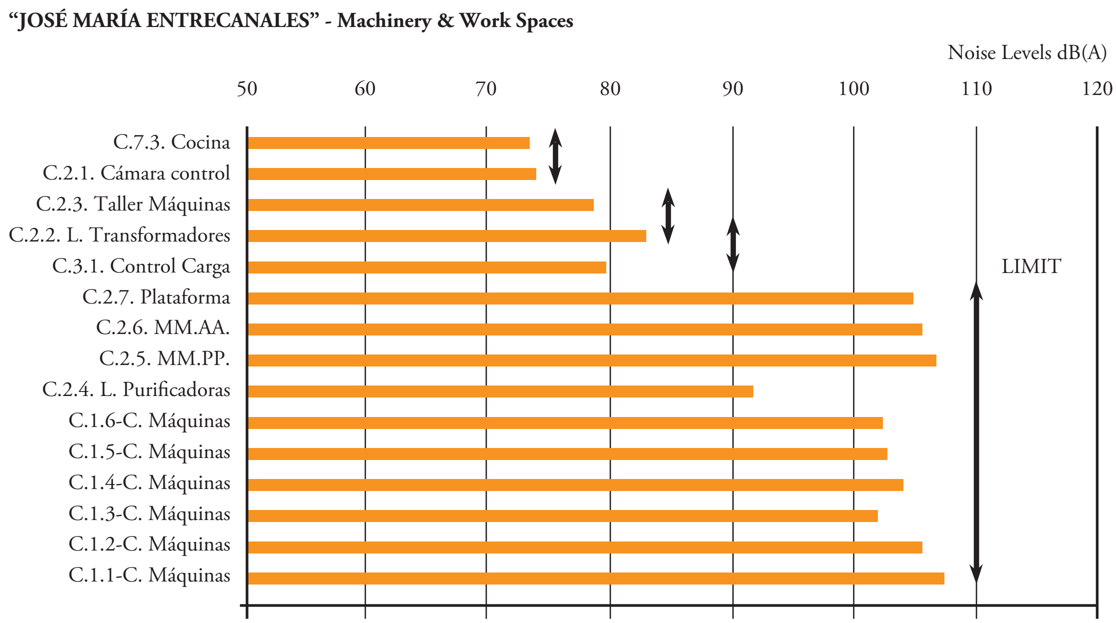
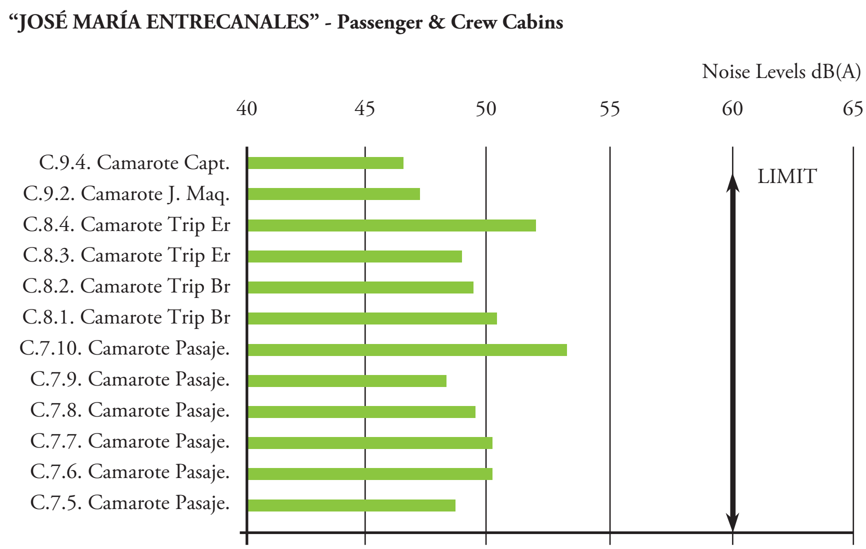


Fig. 18. Noise Levels obtained at different Locations





we can also highlight the following ones:

- In both vessels, noise levels obtained in the different localizations are well below the required limits in the **IMO A.468 (XII) Regulation** [4].
- In both vessels the **IMPROVEMENTS** (deviation respect the limits) obtained oscillate between **-6dB (A) up to -11 dB (A) below contractual limits**.
- In a general way, noise levels obtained in both vessels during the official tests allow us to confirm that the "Acoustic design" in both constructions delivered by **NAVANTIA-Puerto Real**, designed by **SENER** and calculated by the authors, fulfilled satisfactorily the Specification requirements (**IMO A 468(XII)** [5]) even being able to opt for a **Comfort Class 2 or 3**, in the cases that the insulation rate between cabins and public spaces accomplish the minimum requirements of the Classification Societies.

Noise Radiated to the Harbour Results

After the results of the Tests in relation to the measures of Noise Radiated to Harbour by the vessels **"José María Entrecanales"** and **"Super-Fast Baleares"** (Fig. 19), the following remarks are highlighted:

- In both vessels the Noise Radiated to Harbour level at 25m for each side **ARE WELL BELOW** the **80 dB (A)** limits required in the Specification.
- Also the **IMPROVEMENTS** (deviation respect the limits) obtained oscillate between -8.5 dB (A) and -15.2 dB (A) for starboard

Fig. 19. Assessment of the OPTIMIZATION at 1 m

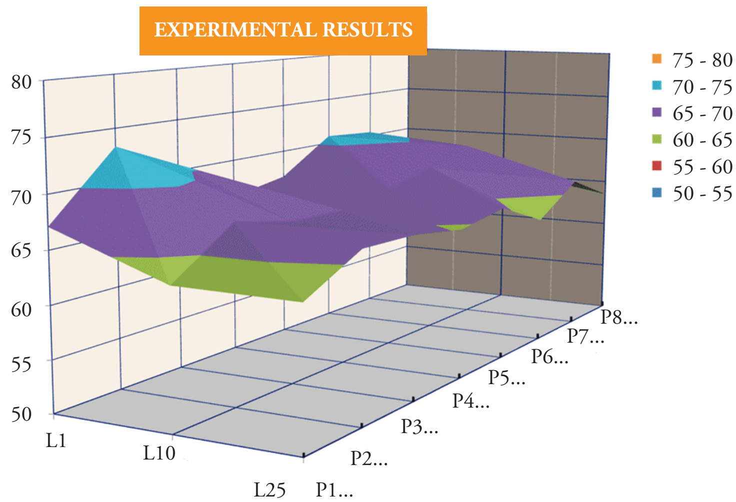
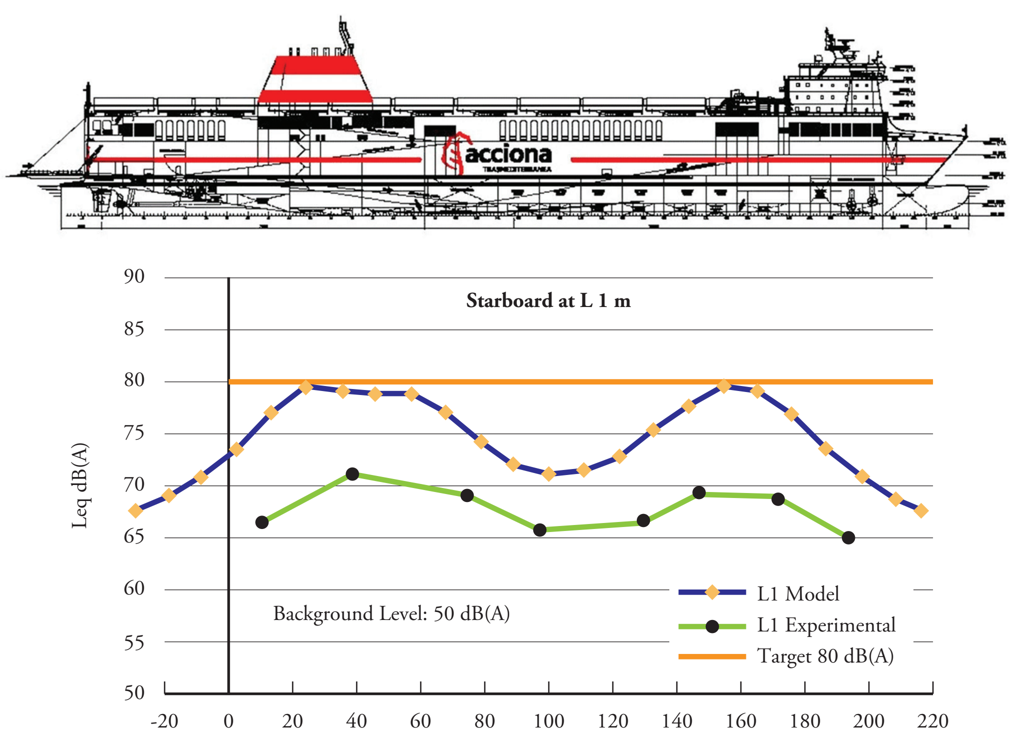
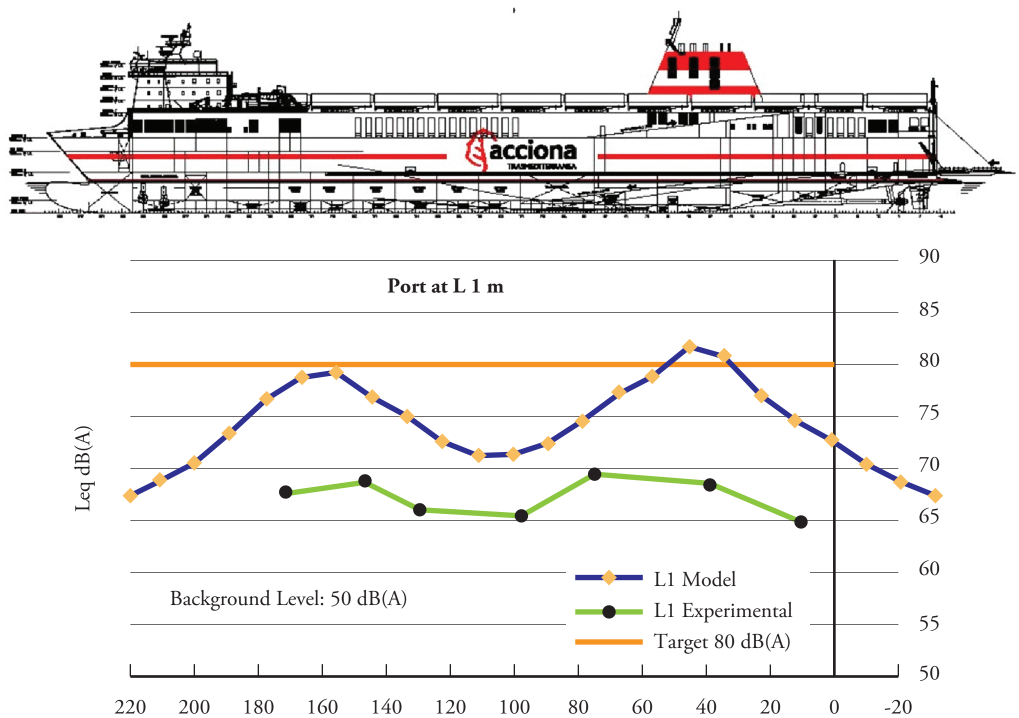


Fig. 20. Correlation: Exterior Noise Radiated Model/Tests" for C-509 at 1m from the side





side and between -11.5 dB (A) and - 15.6 dB (A) for port side, ARE **WELL BELOW THE CONTRACTUAL LIMITS**.

Noise and Vibration Predictions can be considered **"solid"** tools due to several publications about "Model-Test Correlation" that are endorsed by the experience of the authors in the Silent Vessels and the Oceanographic Vessels, in which they have participated [10, 11, 12, 13]. With the new requirement of Noise Radiated to Harbour by vessels, it is necessary that the applied "calculation tools" used must be contrasted with the experimental results obtained. Fig. 20 shows the results of this **"Correlation: Exterior Noise Radiated Model/Tests"** for **C-509 at 1m from the side**.

Analysing these figures it is possible to confirm that this is a "Solid, consistent and conservative tool to predict Noise Radiated to the Harbour by the vessel" as the expected calculation results are between **+5 and +10 dB** (A) over the values experimentally obtained. Security margins which could be taken as appropriate in noise prediction.

Conclusions: Lessons learnt

As it is normal in this type of articles, we present Conclusions and "**our professional experiences related to this work"** as **Lessons learnt** that we modestly submit to sea professionals, in order to enrich this with their contributions and comments and, definitely, to be able to improve the quality and competitiveness of our Marine Sector. Some of the most interesting ones, according to our judgement, are detailed in the following items:

- The recent delivery of the RO-RO vessels **"José María Entrecanales"** and **"Super-Fast Baleares"** to **ACCIONA TRANSMEDITERRÁNEA**, designed by **SENER** and built by **NAVANTIA-Puerto Real,** with vibration levels well below (67%) the **ISO 6954/2000** [5] established limits, noise levels -8 dB (A) below the recommended limits in the **IMO A.468 (XII)** [4], and finally, noise radiated to harbour levels **within the realm of 15 dB (A) below the 80 dB (A) limit required not only in the Specification but also**

in the Community Directives, in force, such as 2002/49/EC [2], achieving an unprecedented fact and becoming an additional technological milestone in the Marine Spanish Sector.

- The **quality of the obtained final product** allows **NAVANTIA-Puerto Real** to reaffirm its position in the selected **"market niche"** of "Silent Vessels", and also, to have a "technically supported reference", in national and international markets where, currently, there is a high demand of these types of vessels.
- The introduction of this Regulatory Framework, due to the fact that it "obliges" the Ship-owners and the managers of the vessel operating companies, in the Specifications is occurring. Well evidenced in the most recent Specifications of all types of vessels in which the author is involved.
- This fact that, some could consider **"a problem"**, the author believes that if we are clever enough it could become a **"new business opportunity"** in our Marine Sector. The author, from his experience with his participation in the R&D European projects (**SILENV AND BESST**) more avant-garde in these aspects, thinks that more would be the advantages than the disadvantages when applying an **"efficient technical answer"** to the new Regulatory Framework. All of the European shipyards (our neighbours) that participated in these projects understood it in this way and their movements are going in this direction.
- For those who may feel **"frightened"** in view of this new Regulatory Framework, that is already included in the Contractual Specification of the vessels, or for those who prefer **"looking at the other side"** facing this new unquestionable reality, we would like to tell them that the answer to the question: Is the National Marine Sector ready to respond to these new and strict requirements? Is definitely **YES**, it is ready.
- In few words, **"we know how to do it"**. We only need to **"know how to sell it"**. It is a hard task but based on our extended experience as a **"survival SME"** we would like to provide some ideas:

  - Ship-owners, nationals and foreigners, **must know and understand** our skills to help them with guarantees in the fulfilling of the new Regulatory Framework that they are forced too. For this: 1) We must **"make noise"**, this means, our achievements in the sector should appear in foreign publications. 2) Our commercial colleagues must, besides knowing the new Directives and their technical and economic implications in the vessel price know and have a **value enhancement strategy**.

  - We must know that **our guarantees on fulfilling** depend on the appropriate tools that we use: **Noise and Vibration Integrated Management**, "contractual commitment" from the suppliers with the shipyard and ship- owner's objectives, data verification provided by reception test in the factory acceptance test (we should not forget that the "absence or inaccuracy" will be paid by the shipyard), we use insulation standardize material (pay now or pay later) and its correct assembly, etc. All this undoubtedly **"add"** and must be considered when making the shipyard understand.

- Finally, these new Directives are seen by some with fear, due to the implications when coming into force. In view of this scene, let's **"have a look at"** other sectors and see what they have done. In concrete, Automobile Sector, in view of the Community Regulations and Directives of emissions reduction, which scared some, **what did they do?**, acting as a "lobby", they decided to invest in all the technical improvements to meet the targets, they knew how to make a good **"business opportunity"** out of what others considered **"a problem"**: "Prever plan" (financed by EU) and the complete renovation, in ten years, of all car fleet in all the European countries. In conclusion **"BUSINESS OPPORTUNITY"**.

References

[1] European Commission Green Paper on Future Noise Policy (COM (96) 54 540). 1996.

[2] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.

[3] BELTRÁN P; TESORERO M. ANTONIA, "Spanish Shipbuilding ready to meet the new and demanding Environmental Requirements: New Challenges and Business Opportunities" Ingeniería Naval No. 887, December. [4] IMO Resolution A.468 (XII): Code on Noise Levels on Board Ships. IMO 1975.

[5] ISO 6954:2000: Mechanical vibration - Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.

[6] ISO 2922/2000 Acoustics -- Measurement of airborne sound emitted by vessels on inland waterways and harbours.

[7] ICES Cooperative Research Report No. 209. Underwater noise of research vessels, review and recommendations. ISSN 1017-6195, May 1995.

[8] ANSI/ASA S12.64-2009/Part 1: Quantities and Procedures for Description and Measurement of Underwater Sound from Ship - Part 1: General Requirements.

[9] DNV Rules for Classification of Ship. New buildings, Special Equipment and Systems Additional Class: Part 6, Chapter 24 Silent Class Notation, January 2010.

[10] BELTRÁN P., "Noise vibration on ship prediction: Basic engineering tool to fulfill the current requirements of comfort and quality". Naval Engineering, October 2001.

[11] BELTRÁN P. AND OTHERs, "Silent Fishing Vessels. A milestone for small and big Spanish shipyards. Lessons learnt.". Separata Naval Engineering, February 2.006.

[12] BELTRÁN P., "Oceanographic ship Miguel Oliver". Naval Engineering No. 848, May 2007.

[13] BELTRÁN P. "Oceanographic Ship "Miguel Oliver": The excellence on Noise and Vibration on board fulfilling ICES- Nª209. First Prize 47th Congress of Naval Engineering and Maritime Industry. October 2008.

[14] ENCISO FERNÁNDEZ, C., "About noise and vibration transmission in the MAPA 70 of M. Cies shipyard" Naval Engineering. May 2007.

[15] PÉREZ GÓMEZ G., PÉREZ SOBRINO M., GONZÁLEZ-ADALID J., GARCÍA GÓMEZ A., MASIP HIDALGO J., QUEREDA LAVIŃA R., MINGUITO CARDEŃA E., BELTRÁN P., "A milestone in the Spanish naval propelling. Profitability of a wide R&D program. 75th Anniversary Award. AINE. Naval Engineering, June 2006.

Optimization of a warehouse layout used for storage of materials used in ship construction and repair

Optimización del esquema de bodegas utilizadas para el almacenamiento de materiales de construcción y reparación naval

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Abstract

The paper shows the evaluation of applying models to improve efficiency in management of warehouses used in shipyards, focused on pick up, packing, and shipping activities, supported among others on the proposal by Rosenblatt and Roll (1984) to optimize the layout for storage and handling of materials needed for ship construction and repair. Besides proposing the best physical layout for the storage of goods, the model seeks to minimize three types of costs: costs related to the initial investment (construction and maintenance), shortage costs, and costs associated with storage policies. The optimal design is found through analytical optimization and simulation techniques.

Key words: Warehouse, Storage, Rosenblatt and Roll model, Ships

Resumen

El articulo muestra la evaluación de la aplicación de modelos para mejorar la eficiencia en el manejo de bodegas utilizadas en astilleros, centrada en actividades derecolección, embalaje y envío, soportada entre otras en la propuesta de Rosenblatt y Roll (1984) para la optimización del diseño para el almacenamiento y manejo de los materiales necesarios para la construcción y reparación de buques. Además de proponer la mejor distribución física para el almacenamiento de las mercancías, el modelo busca minimizar tres tipos de costos: costos asociados a la inversión inicial (construcción y de mantenimiento), un costo de escasez y los costos asociados con las políticas de almacenamiento. El diseño óptimo se desarrolla con una combinación de optimización analítica y técnicas de simulación.

Palabras claves: Bodega, Almacenamiento, Modelos de Rosenblatt y Roll, Buques

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Introduction

The analysis of warehouses refers to the location of the various departments (reception, selection, storage, sorting, and shipping), as well as to their distributions. The common goal is to minimize handling costs, which in many cases are represented by a linear function of the distances covered and that in terms of logistics costs can represent up to 20%. Tompkins *et al*., (2003) state that the purpose of the layout is to minimize handling costs, generally represented by a linear function of the distance traveled.

In the design of a warehouse/storage building should consider the overall structure, size and dimension, features of departments, selection of its strategic operation, and equipment to be used in the storage process. During the overall design, material flow patterns, functions of each department (reception, selection, storage, sorting, and shipping), and the relationships flow that should exist among its sections is determined. Activities of receiving and pick up, (Pick up/Packing) are considered relevant given the cost implications involved and these are influenced and affected by the type of warehouse design considered.

Gu and Goetschalckx (2010) discussed the design of the storage department and typify the main problems to be solved, classifying them thus: identify storage stacking platform, depth of storage lanes, and existing number of lanes. Other issues to be solved are location of the main entrance door, orientation of lanes, and number of lanes that must exist throughout the warehouse. Finally, the number of cranes and the dimensions of storage racks mmust be addressed.

The design of the storage department exposed by Gu and Goetschalckx (2010) affects the performance of the warehouse with respect to construction costs, holding costs, labor costs, storage capacity, use of space, and use of equipment.

The Rosenblatt and Roll (1984) model seeks an optimal solution to the physical layout and design of a storage building, considering the amount of entry and exit ways, the location of these doors, the number of aisles and their orientation and dimensions. It also takes into account the warehouse capacity and storage policies, as decision variables to apply optimization techniques that are characteristic of the model. The Rosenblatt and Roll (1984) model proposes optimization of three types of costs: *Costs associated with the initial investment (construction and maintenance), shortage costs, and costs associated with storage policies*. The subsequent investigation to find the optimum design of storage is developed by comparing analytical optimization and simulation techniques.

The type of storage building that Rosenblatt and Roll (1984) have proposed in their model is a warehouse with only one physical plant, where products can be arranged on shelves with a calculated amount of levels, on pallets or stacked. Besides, it must be taken into account that this model considers the random storage policy where, in areas dividing the warehouse, goods can be randomly arranged; no considerations are made about the composition of products or how they should be accommodated. In this model, equipment for handling and internal transport of goods should be available, especially when considering high shelves to store products, to take advantage of all the warehouse space and decrease the number of shipments rejected because of lack of space. This equipment permits access to products in high places, leading to good inventory turnover.

The model is a good study reference because, in addition to proposing different types of layouts and providing the best physical space for storage of goods, it intends to minimize three major costs in terms of design, material handling, and storage; therefore, it is considered a prototype model that combines important aspects of interest to current companies that seek storage solutions while minimizing operating costs.

Literature review

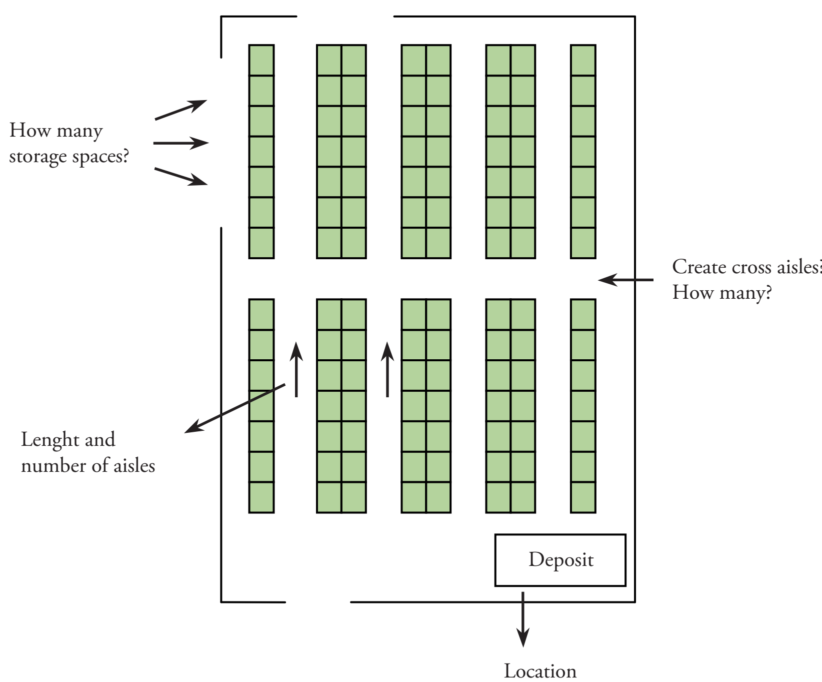
According the Layout topic, relevant studies in this field are described; the Rosenblatt and Roll (1984) model simultaneously addresses three objectives: warehouse size, internal distribution, and storage policies. The literature dealing with layout problems is combined with traditional storage processes (pick up, packing, shipping), describing the complexities of these activities and the need to address these issues jointly.

Berry (1968) found that warehouse distribution could minimize maintenance costs of materials. Francis (1967), Francis and White (1974), Roberts and Reed (1972), and Bassan, Roll and Rosenblatt (1980) found the design of the internal layout of a warehouse to minimize its construction costs and handling costs for materials. Several designs of the internal layout of a storage building have been compared (Bassan, Roll and Rosenblatt; 1980), where the effects of the costs where associated to the perimeter of the storage and the materials handling but are not associated to the cost of the warehouse area. This is consistent with Francis (1967), who assumed that the storage area is predetermined and considered only the costs of materials handling and costs of the perimeter. The problem of warehouse size was considered by White and Francis (1971). The costs considered on their study were, construction costs, assuming they are proportional to store size, storage costs, and evaluation costs – when there is a shortage of available space for storage. A Roll and Rosenblatt (1983) document compares a series of storage policies and their effects in the capacity of a warehouse. Hausman, Shwarz, and Graves in two of their papers (1977, 1976) developed rules for optimal allocation of storage and the sequence of storage in a warehouse of auto design(WHAT DO YOU MEAN BY THIS?). To assume feedback knowledge for various products (or product groups), they developed storage allocation and intercalated policies that achieve significant reduction in travel time of a crane.

Tompkins *et al*., (2003) described different effective procedures for layout design; Heragu *et al*., (2005) provided a model and a heuristic for the dimensioning of areas and the allocation of products to the areas. In general, the design of internal arrangement, or aisle configuration problem, which includes determining the number of blocks, number, length and width of aisles in each block is depicted in Fig. 1.

Roodbergen (2001) proposed a nonlinear objective function (the average travel time in terms of the number of collections (pickups) by trade and

Fig 1. Location Decisions



Source: Authors

islands) to determine aisle configuration for storage deposits by using non-dedicated systems, *i.e.*, random (including single and multiple blocks) that seek to minimize the duration of the tour.

Compared to manual pick up systems and order preparation, the layout design problem taking the load unit (Mainly Automated Storage/Retrieval Storage (AS/RS) systems) has received much attention. This case concerns investigations by Sarker and Babu (1995), Johnson and Brandeau (1996), and Van den Berg (1999).

For random storage assignment, Bozer and White (1984) show relevant studies in this regard. Larson *et al.*, (1997) use a heuristic approach to the design of the load unit in a warehouse and to assign types of goods to locations, in order to increase space utilization and reduce travel distance.

Eldemir *et al.*, (2004) give estimates of storage needs. Park and Webster (1989) address the problem of finding locations for types of products to minimize travel time. De Koster and Le-Duc (2005) extend Bozer and White (1984) to determine the optimal size of a rack of three dimensions of capacity and to minimize recovery time of the load unit.

Reiterating on the Rosenblatt and Roll (1984) model, two data sets are assumed to be known for the procedure. The first data set consists of the distributions that govern the arrival and the composition of products to be stored. The second is the set of approximate cost models, combining the cost components to the configuration of the distribution, storage policies, and shortage in storage capacity. An approximate combination of optimization techniques is applied to determine the total cost as a function of two decision variables: capacity of warehouse and storage policies. Then, by comparing the costs of possible combinations of these variables, we obtain a global optimum storage size, configuration, and storage policies.

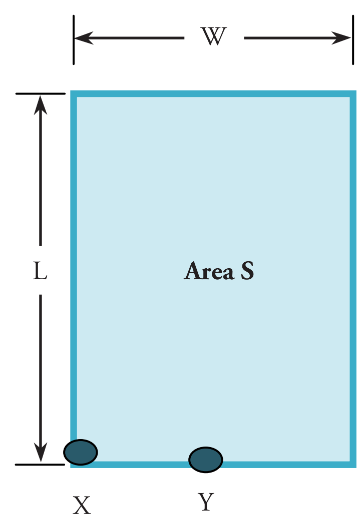
Literature on these issues is abundant; however, it is found that the level of application in different industries and particularly in Colombian Shipyards is very low. Publications like those by Bassan et al., (1980) and Rosenblatt and Roll (1984) use analysis and simulation methods to study the effects of the storage policy (*i.e.*, how to assign products to storage locations) in relationship to the internal storage design. Also, Rosenblatt and Roll (1988) examined the effect of stochastic demands and different levels of service in the warehouse layout and storage capacity.

This literature review on layout investigations shows the relevant studies by Bassan, Rosenblatt and Roll that serve as pivot for the analysis involved in the characterization and improvement proposal for COTECMAR, adjusted to the conditions of existing resources and the size of the configuration presented by the central warehouse of the Corporation.

Nomenclature and basic models

Based on the figure below, for a rectangular warehouse with a W width and an L length, with floor area of S, the following relationships were found:

Fig 2. Size of a rectangular warehouse



Source: Authors

C = Sum of total cost per unit of length to move an item multiplied by the expected number of items per year ($/ft)
K = annual cost of perimeter ($/ft)
S = Area of the warehouse (ft^2)

CT_X, CT_Y = total relevant cost for setting X, Y [$/year]

Exit/Entry Door located in X:

$$W^* = \sqrt{\frac{C + 8k}{2c + 8k}}\sqrt{S} \quad (1)$$

$$L^* = \frac{L}{W^*} \quad (2)$$

$$CT_x = 2\sqrt{\left[\frac{C}{2} + 2K\right]\left[\frac{C}{4} + 2K\right]}\sqrt{S} \quad (3)$$

Exit/Entry Door located in Y:

$$W^* = L^* = \sqrt{S} \quad (4)$$

$$CT_y = \left[\frac{C}{2} + 4K\right]\sqrt{S} \quad (5)$$

Shelf and aisle configuration - Notation

W = width of a double-sided shelf [ft]
L = length of each storage space (for example, the width of a pallet [ft])
m = Number of storage spaces along a shelf
h = Number of storage levels in the vertical direction
n = number of double-sided shelves, two simple shelves are considered equal to a double shelf
K = total capacity of storage space in the warehouse
a = width of an aisle [feet], assuming that all have the same width
u = length of the warehouse [ft]
v = width of the warehouse [ft]
d = annual demand of the warehouse in storage units (e.g., pallets). It is assumed that a storage item uses a storage unit [items/year]
Ch = cost of material handling, of moving an item a unit of length [/ft]
Cs = annual cost per unit area of the warehouse, for example: air conditioning, electricity, maintenance [$/ft^2]
Cp = annual cost per unit of length of external walls [$/ft]

The optimal number of storage spaces depends on the distribution figure adopted; a typical example for a situation with aisles in front of the door:

$$m_1^* = \frac{1}{L}\sqrt{\left[\frac{dC_h + 2aC_s + 2C_p}{2(dC_h + C_p)}\right]\left[\frac{K(w+a)L}{2h}\right]} \quad (6)$$

And the optimal number of double-sided shelves is:

$$n_1^* = \frac{1}{w+a}\sqrt{\left[\frac{2(dC_h + 2C_p)}{dC_h + 2aC_s + 2C_p}\right]\left[\frac{K(w+a)L}{2h}\right]} \quad (7)$$

Thus, the best configuration of the warehouse would have an optimum length of:

$$u_1^* = n_1^*(w + a) \quad (8)$$

And an optimum width of:

$$v = 2a + m_1^* L \quad (9)$$

For cross-aisle layout, the optimal results are:

$$m_2^* = \frac{1}{L}\sqrt{\left[\frac{2dC_h + 3aC_s + 2C_p}{dC_h + 2C_p}\right]\left[\frac{K(w+a)L}{2h}\right]} \quad (10)$$

$$n_2^* = \frac{1}{w+a}\sqrt{\left[\frac{dC_h + 2C_p}{2dC_h + 3aC_s + 2C_p}\right]\left[\frac{K(w+a)L}{2h}\right]} \quad (11)$$

$$u_2^* = 3a + m_2^* L \quad (12)$$

$$v_2^* = n_2^*(w + a) \quad (13)$$

To minimize costs between these two alternative designs, the following decision rule can be applied:

- If d <Cp / Ch, select configuration 1
- If d> 2Cp / Ch, select configuration 2
- If Cp / Ch <d <2Cp / Ch, cannot conclude

Metodology

To propose improving the layout of the central storage warehouse oat COTECMAR, we performed *in situ* characterization of the infrastructure, processes, and activities associated with storage through observing them and with surveys and interviews of the staff responsible of this process within the Corporation. Fieldwork was conducted by using tools for collecting, tabulating, and analyzing data to obtain and collect information associated with the flow of materials within the warehouse, as well as in and out of it.

Additionally, information was obtained on the logistics infrastructure of the Corporation, which included making drawings of the different storage spaces in dimensions and storage equipment to obtain the storage capacity at COTECMAR in square and cubic meters.

COTECMAR's logistics infraestructure

COTECMAR has two main headquarters located in the ports of Mamonal (Industrial Sector) and Bocagrande (Tourism Sector) in the city of Cartagena de Indias, Colombia. The company has warehouses for the storage of materials and supplies needed for operations at both sites.

At the Mamonal headquarters, there is a central storage building, a warehouse to store materials for the Offshore Patrol Vessel (OPV) construction project and areas for storage of specific materials. The central warehouse at Mamonal, the objective of this study, stores materials necessary for construction and repair projects and for the operation at the COTECMAR facilities. This warehouse has spaces for materials requiring special storage conditions.

The warehouse has a welding room equipped with temperature-control equipment to maintain the solder under controlled conditions in accordance with the specifications for these materials. Similarly, the warehouse has two rooms with air conditioning to store materials and equipment that cannot be kept at room temperature, like resins, oils, adhesives, and special material for the OPV project. These rooms also store the warehouse's physical files.

COTECMAR'S central warehouse has 1169 m^2 in areas of material receipt, storage, pick up and shipping. The aggregate capacity of the central warehouse is 5369 m^3.

In 2009, COTECMAR started a project of Adaptation and Modernization of the storage buildings and other storage areas. The project was designed to optimize the storage of materials

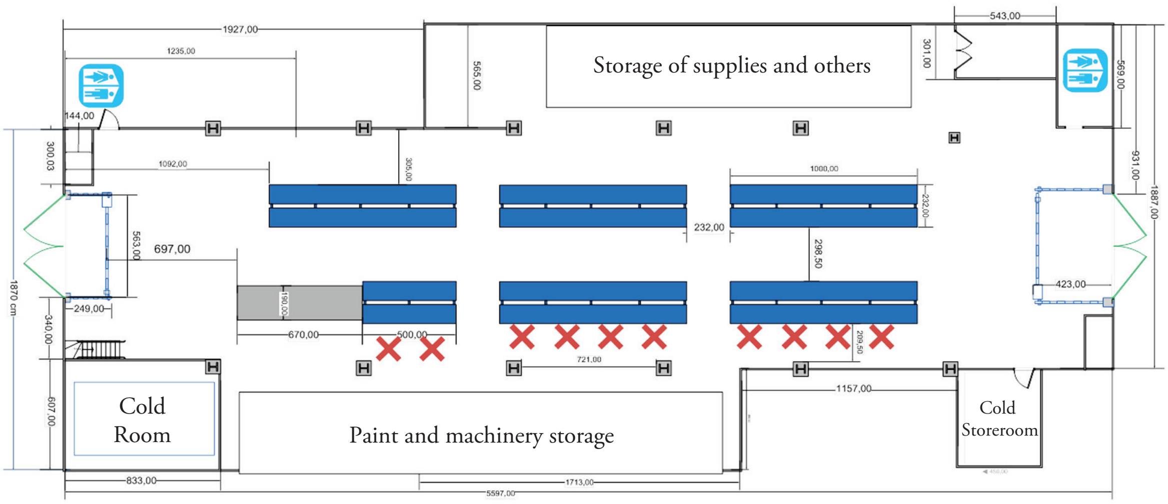
Fig 3. Central Warehouse at the Mamonal plant

through the adaptation and modernization of the existing system to meet present and future corporate challenges. The central warehouse at the Mamonal plant has an area of 1170 m^2, after the expansion and investments that included demolishing the former composites workshop and expanding the warehouse. In 2009, the area of this central warehouse was of 723 m^2.

Furthermore, the way the shelves were located did not permit full maneuverability of loading equipment in the warehouse. As illustrated in Fig. 4, a whole aisle of shelves was inaccessible by the forklift because of the height conditions of the warehouse in the lateral zones. In this zone, the merchandise must be located manually by the operators, placing them at risk and rendering as inefficient the operations of material location and pick up.

Despite investments in the warehouse to be consistent with the needs of new construction projects, acquisition of handling equipment and shelving and preparation of areas for the conservation and storage of special materials (solder, electronic elements), the physical layout of the central warehouse at Mamonal does not follow any criteria, except for the storage of certain materials under special temperature conditions.

Fig 4. Forklift maneuverability



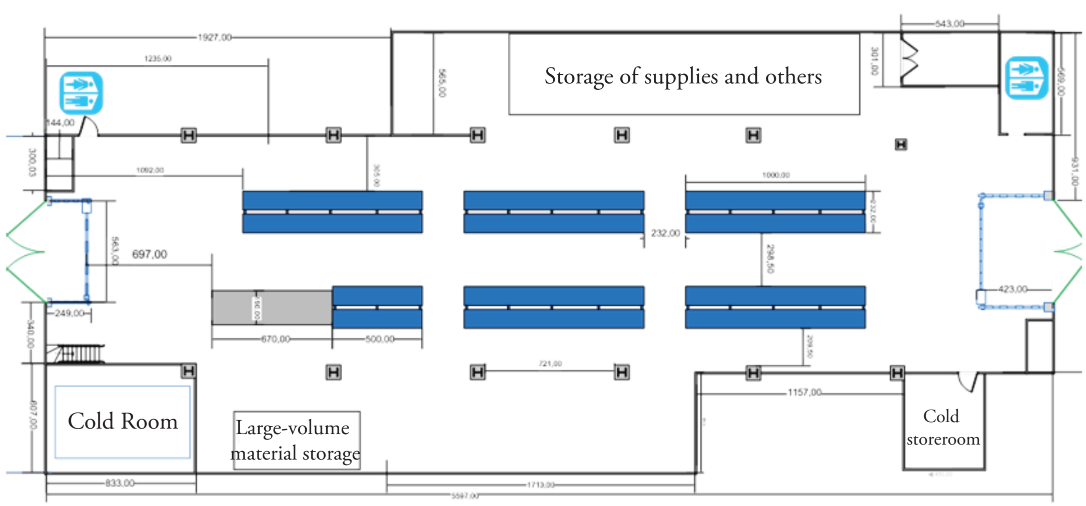
Source: SEPRO and GICO Research Group

Reestructuring the layout of the central warehouse at the Mamonal plant

The distribution of the central warehouse at the Mamonal plant is shown in Fig. 5. This arrangement has several drawbacks from the logistics point of view, which will be discussed and solved in the restructuring proposal.

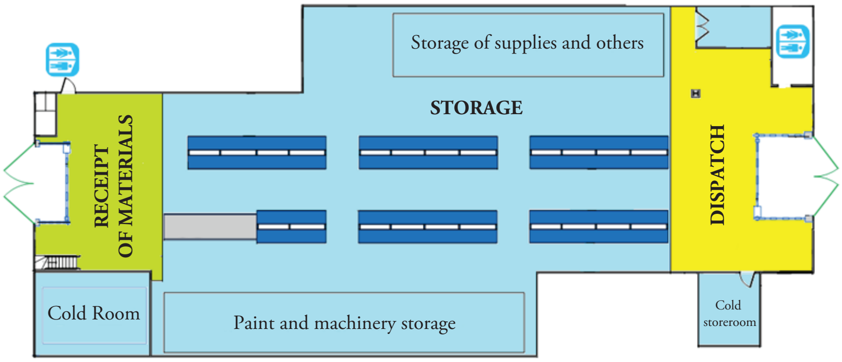
The warehouse has a linear distribution, as shown in Fig. 6.

Fig 5. Current arrangement of the Cotecmar central warehouse



Source: GICO-SEPRO Research Group

Fig 6. Warehouse distribution



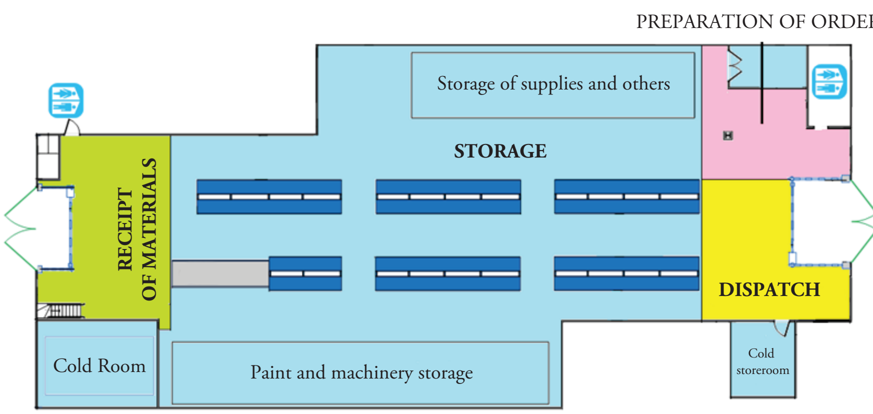
Source: GICO-SEPRO Research Group

Fig. 6 clearly identifies reception and storage of material areas, but also notable is the absence of an area to prepare orders. This can be attributed to the following problems encountered in the warehouse:

- Delays in the process of order compliance
- Aisles obstructed
- Delays in activities of storage and pick up of materials from shelves due to obstructed aisles
- An obstructed aisle means three things for the warehouse: 1. Higher costs of internal transportation of materials; 2. Decrease in the amount of usable space in the warehouse; 3. Expenditure on(NOT CLEAR) staff resource, which can be used in other functions such as cleaning or performance improvement activities in the warehouse.

To tackle these problems, we recommend clearly establishing the order preparation area. The size of the pickup area should be as shown in Fig. 7.

Fig 7. Redistribution of warehouse zones



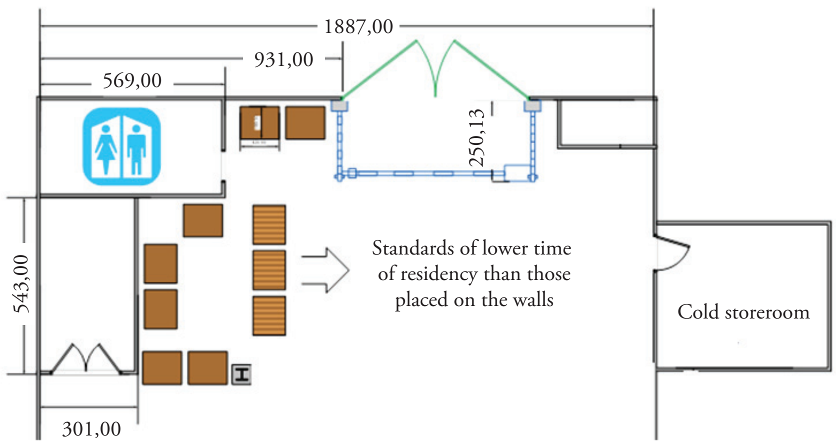
Source: GICO-SEPRO Research Group

According to this figure, we can determine that:

- For the operating conditions of the warehouse, the area designated for the reception is properly sized.
- The area dedicated solely to delivery, under the present conditions, must be shared with the area allocated for pickups or order preparation. Thus, before shipping an order, it should be organized and processed in this new area.

With the setting recommended, mainly referring to Rosenblatt and Roll, the order preparation area allows accommodating up to 10 pallets of temporary storage, permitting normal operation with the forklift for seven of them, as shown in Fig. 8. These 10 pallets provide sufficient space to ensure that any order can be prepared in that area, preventing obstruction of the aisles during the process of collecting materials in the warehouse.

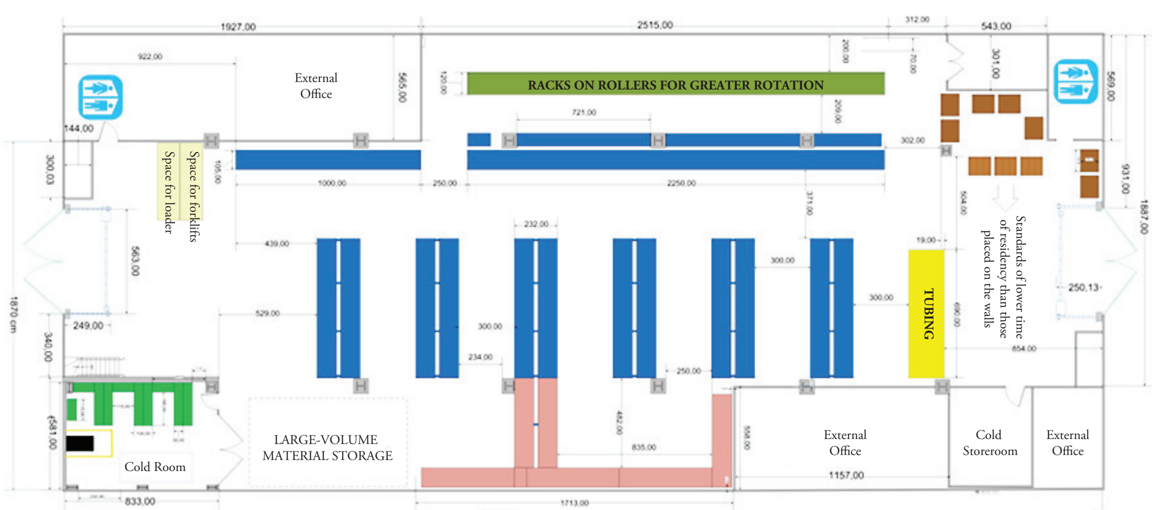
Fig 8. Structuring the pickup area



Source: GICO-SEPRO Research Group

In order to increase storage capacity and mobility of the central warehouse at the Mamonal plant, restructuring the layout is proposed, as shown in Fig.9.

Fig 9. Restructuring the central warehouse at the Mamonal plant



Source: GICO-SEPRO Research Group

This restructuring comprises several changes, which allow achieving the following objectives:

f) Maximum use of the volume of the warehouse.
g) Use of all storage shelves.

h) Improve mobility in the warehouse.
i) Improve reception, dispatch, and order pick up areas.
j) Adjust and improve the storage areas of paints and screws.

The central rack, in blue in Fig. 9, is responsible for storing the materials that can be stored on pallets and that have regular dimensions. Table 1 furnishes a summary of current variables and those provided by the new distribution.

Table 1. Comparison of current storage model and the one proposed

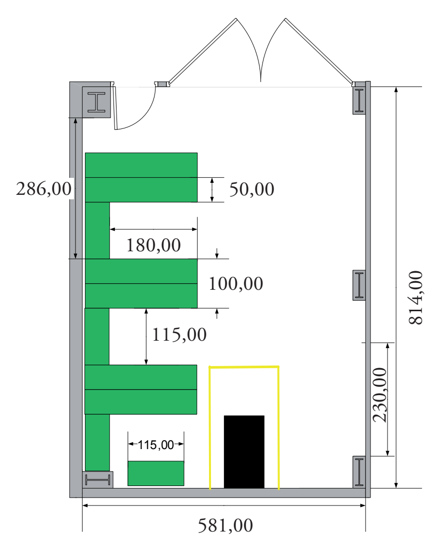
Description	Current	Proposed
Possible storage positions	208	245
Obstructed positions	48	0
% Obstructed positions	23%	0%
Positions actually used	160	245
Increase in the number of positions	18%	
REAL INCREASE (Real storage positions)	53%	

Source: GICO-SEPRO Research Group

The area of material on consignment is configured as shown in pink in Fig. 9. This design corresponds to a better use of space, allowing the entry of the forklift because most of the materials coming into this area are paints, which very often enter the warehouse organized in pallets. Furthermore, this structure is according to the organization of the central shelf, allowing greater mobility and flexibility for daily operating activities in the warehouse. The shelf corresponding to this area is the same as that established for the central storage area, allowing the possibility of storage during a peak period, so palletized materials can be stored in this area due to the possibility of forklift maneuverability, which provides flexibility to the warehouse.

The physical file storage area must be transferred to the cold room in the first floor of the offices according to warehouse management requirements. This requires designing the shelving necessary for the material, taking into account only the use of half the available space in the room, where there is a rack system rack – which is not removable, and the rest of the room should be used to store containers on the floor with materials that require temperature-controlled conditions. The storage volume required for the file zone is of 20.08 cubic meters. Fig. 10 shows the distribution of the shelf designed for file storage and stationery. This shelf has 5 levels, reaching a height of 2.72 m, the shelf width is 50 cm and the standard length is 1.15 m. The storage volume obtained with the proposed distribution in Fig. 10 is 21.62 cubic meters, which is completely satisfactory for the proposed storage.

Fig 10. Design of the file storage area

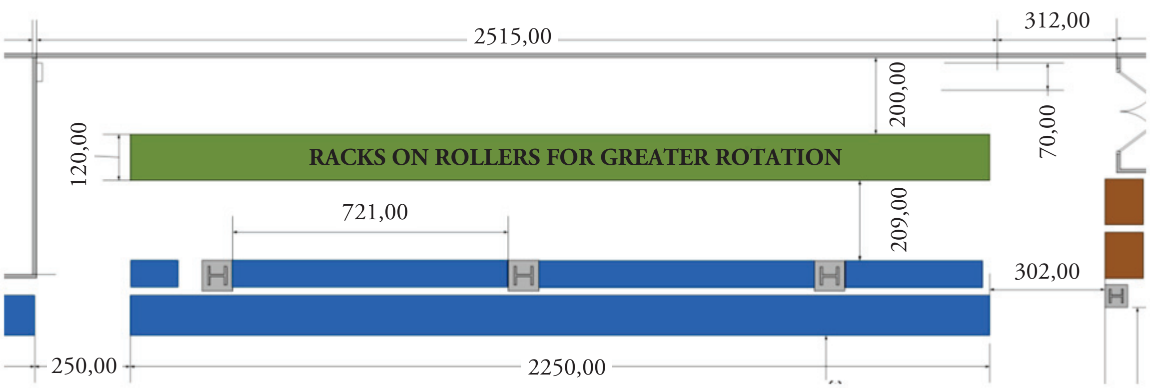


Source: GICO-SEPRO Research Group

Fig. 11 shows the design of the storage area for screws, valves, and other materials. This design is based on using a sloping shelf (green shelf) in which the material is loaded by the side of the wall, and due to this tilt the materials will move automatically to the other side by which these elements will be removed. This will ensure that older materials are those that are taken out first, following the First In First Out (FIFO) sequence. It is recommended that this shelf holds rollers, which facilitate moving items stored.

On the same side where the elements are removed is a conventional shelf 70 inches deep and 4 heights. This rack can store material with low turnover, while increasing storage capacity in this area of the warehouse.

Fig 11. Comparison of current storage model and the one proposed



Source: GICO-SEPRO Research Group

Conclusions

The restructuring of the proposed layout for the central warehouse at the Mamonal COTECMAR headquarters clearly establishes the areas in which the warehouse should be divided so that there should be an area different from order preparation to solve the problems of obstructed aisles and delays in order fulfillment and storage and collection of materials. By allocating an area for this purpose, the costs of transport of goods in the warehouse are reduced and the usable storage space is increased.

The proposed restructuring of the shelves in the area of the warehouse for the storage will also achieve a maximum use of the warehouse, ensuring accessibility of the forklift to the entire shelf and improving the provision of specific storage areas such as consignment of paints, coolers, and ironmonger area. The proposed layout design for the warehouse ensures better use of space and access to all storage areas, allowing greater mobility and flexibility for daily operating activities of the warehouse.

References

BASSAN, Y., ROLL, Y., ROSENBLATT, M.J., 1980. Internal layout design of a warehouse. AIIE Transactions 12 (4), 317–322.

BERRY, J.R., 1968. Elements of warehouse layout. International Journal of Production Research 7 (2), 105–121.

BOZER, Y.A., WHITE, J.A., 1984. Travel-time models for automated storage/retrieval systems. IIE Transactions 16, 329–338.

ELDEMIR, F., GRAVES, R.J., MALMBORG, C.J., 2004. New cycle time and space estimation models for automated storage and retrieval system conceptualization.

International Journal of Production Research 42 (22), 4767–4783.

FRANCIS, R.L., "On some problems of rectangular warehouse design and layout," Jou. Of Ind. Eng., Vol. 18 (1967), 595 -604.

FRANCIS, R.L., 1967. On some problems of rectangular warehouse design and layout. The Journal of Industrial Engineering 18, 595–604.

GU, GOETSCHALCKX AND MCGINNIS (2010) Research on warehouse design and performance evaluation: A comprehensive review European Journal of Operational Research 203 (2010) 539–549.

HERAGU, S.S., DU, L., MANTEL, R.J., SCHUUR, P.C., 2005. Mathematical model for warehouse design and product allocation. International Journal of Production Research 43 (2), 327–338.

HAUSMAN, W.H., SCHWARZ, L.B., GRAVES, S.C., 1976. Optimal storage assignment in automatic warehousing systems. Management Science 22 (6), 629–638.

JOHNSON, M.E., BRANDEAU, M.L., 1996. Stochastic modeling for automated material handling system design and control. Transportation Science 30 (4), 330–350.

LARSON, T.N., MARCH, H., KUSIAK, A., 1997. A heuristic approach to warehouse layout with class based storage. IIE Transactions 29, 337–348.

PARK, Y.H., WEBSTER, D.B., 1989. Design of class-based storage racks for minimizing travel time in a three dimensional storage system. International Journal of Production Research 27 (9), 1589–1601.

ROBERTS, S.D., REED, R., 1972. Optimal warehouse bay configurations. AIIETransactions 4 (3), 178–185.

ROODBERGEN, K.J., 2001. Layout and routing methods for warehouses. Ph.D. thesis, RSM Erasmus University, the Netherlands.

ROSENBLATT, M.J., ROLL, Y., 1984. Warehouse design with storage policy considerations. International Journal of Production.

SARKER, B.R., BABU, P.S., 1995. Travel time models in automated storage/retrieval systems: A critical review. International Journal of Production Economics 40, 173–184.

TOMPKINS, J.A., WHITE, J.A., BOZER, Y.A., FRAZELLE, E.H., TANCHOCO, J.M.A., 2003. Facilities Planning. John Wiley & Sons, NJ.

VAN den BERG, J.P., 1999. A literature survey on planning and control of warehousing systems. IIE Transactions 31, 751–762.

WHITE, J.A., FRANCIS, R.L., 1971. Normative models for some warehouse sizing problems. AIIE Transactions 9 (3), 185–190.

Methodological design of a performance measurement system for the colombian shipyard supply chain

Diseño metodológico de un sistema de medición del desempeño para la cadena de suministros de astilleros en Colombia

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Abstract

The design of a performance measurement system for the Colombian shipyard supply chain is shown in this paper, using a model that integrates the principles of the Balanced Scorecard with the fuzzy sets theory to treat uncertainty associated with selected logistics indicators, enabling better supply chain management.

Key words: Indicator, performance measurement, supply chain, fuzzy logic, Balanced Scorecard, shipyard.

Resumen

El presente artículo muestra el diseño de un sistema de medición del desempeño para la cadena de suministros de los astilleros colombianos, usando un modelo que integra los principios del *Balanced Scorecard* con la teoría de conjuntos difusos para el tratamiento de la incertidumbre asociada a los indicadores logísticos seleccionados, posibilitando mejor gestión de dicha cadena.

Palabras claves: Indicadores, medición del desempeño, cadena de suministros, lógica difusa, *Balanced Scorecard*, astilleros.

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Introduction

Modern global environment changed the focus of business rivalry, from a competition between individual organizations to supply chain rivalry. A supply chain is a network consisting of suppliers, manufacturers, warehouses and wholesale distributors, and retailers who – through coordinated plans and activities – develop products that will increase their added value as they flow up the final consumer to meet their needs and requirements. Regardless of the approach, product type or size of operations, supply chain performance is what will determine its ability to generate customer value. Therefore, organizational management requires developing performance measurement systems adapted to the presence of various companies, which is considered one of the most impacting tools on supply chain management (*Ballou et al., 2000; Lancioni, 2000*).

Generally, performance measurement has had an intra-organizational approach and although discussions and frameworks appear in the literature about performance measures in supply chains, there is a lack of empirical analysis and case studies on metrics and performance measurement systems within the context of supply chains, more so in the case of Colombia. That is why this paper aims to develop a methodology for designing a performance measurement system for the supply chain in uncertainty environments, in a case applied to the Colombian design, construction, maintenance, and repair of ships and the naval industry. A model integrating the principles of the Balanced Scorecard (BSC) with the fuzzy-set theory to deal with the uncertainty associated with the selected logistics indicators, enabling better supply chain management is proposed.

Fuzzy logic application in performance measurement has had some developments in recent years, especially by various researchers in the Asia-Pacific region. The most relevant works were profusely published from 2000, approximately, starting with Lau *et al*., (2002) who developed a methodology to analyze and monitor supplier performance in a supply chain based on product quality and delivery time criteria. Ling *et al*., (2006) developed an indicator to evaluate agility in supply chains by using fuzzy logic to deal with ambiguity because they believe that this is a useful tool for making decisions in which the phenomena are vague and imprecise. The fuzzy indicator focuses on linguistic approach application and fuzzy arithmetic to synthesize fuzzy numbers to obtain the agility index of manufacturing operations.

Silva *et al*., (2007) used fuzzy weighted aggregation to formulate logistics systems optimization problems, which can be extended to different optimization method types like genetic algorithms or ant colonies. Another important work was done by Kanda and Deshmukh (2007), who applied the fuzzy logic approach combined with AHP in assessing the coordination level among supply chain members. Similarly, Ohdar and Kumar (2004) developed a fuzzy methodology based on genetic algorithms for supplier performance evaluation.

This article is structured as follows: first, a description of shipyard supply chains and a conceptual review of performance measurement in supply chains are made. Then, we present the evolution of research on the subject through the different approaches that have had scientific production on the issue. Thereafter, we establish the proposed methodology, the theoretical aspects, and the application form. Lastly, we show the results obtained by applying said methodology and their analysis is made along with the conclusions.

Shipyard Supply Chains

Implementing supply chain management initiatives requires classifying them according to the specific market characteristics and the life cycle of products, industry type, as well as degree of product customization, business strategy, and organizational skills.

A shipbuilder is basically an assembly plant on structural steel. However, it has an important subsidiary component of manufacturing activities for cutting, bending, and shaping steel plates and pipes according to the ship's design specifications.

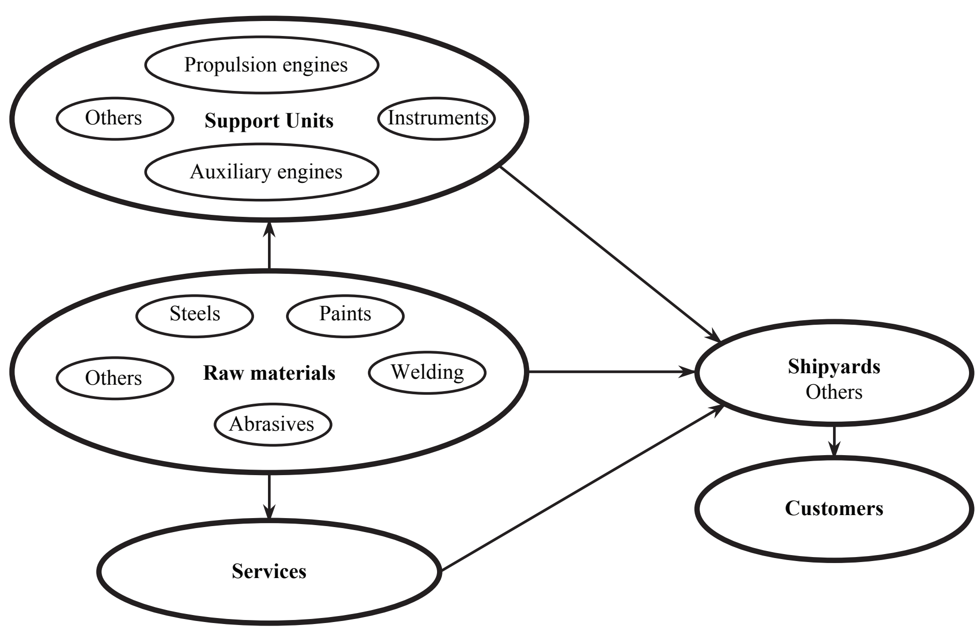
Incorporating advanced techniques of production planning has allowed the construction of boats from subunits or modules with pre-integrated facilities and systems, which are combined to form the vessel. A repair shipyard performs various activities, which require high flexibility and adaptability to customer needs.

Naval, maritime, or fluvial construction or repair projects are divided into a number of subprojects conducted generally by contractors, which must deliver a ship´s operating area. This must consider operations, shipyard supply chain performance engineer-to-order (ETO) and made-to-order (MTO) operations. In ETO chains, the critical point is the design stage so that each order (ship building or repair in the shipyard) has a particular design stage (Gosling and Naim, 2009) largely determined by the customer, and develops simultaneous multiple products with different specifications and stages of the manufacturing process (*Abdul and Nabi, 2003*). In MTO chains, the critical point lies in the manufacture and purchase of raw materials and inputs (*Olhager, 2003*) and reducing delivery time is not a fundamental purpose because of the disparity of these depending on the intervention need.

Delivery time of supplies and spare parts is a critical point in repair projects because of their short duration (from seven to fifteen days or so) and there is high demand for deadline compliance from the customer. Out-of-service ship fixed costs are very high (crew salaries, ship affreightment), days of shipyard cost, and lost transport service billing are loss factors for ship owners. It is also quite common to make adjustments to initial materials and supplies requisition as requirements vary during development of repair activities.

Based on relationships and materials flow between facilities, in general, shipyard supply chains may be convergent (Fig. 1), given that each node or facility has more than one successor, but may have any number of predecessors (*Beamon and Chen, 2001*). Usually, shipyards do not have a commercial distribution system of repaired or built vessels; the product is delivered in the shipyard to ship owners who carry it to the final destination. The shipyard may assume a dominant position because it is the backbone of the supply chain, by determining the operations and performance, making a network organization in an Extended Enterprise (*Capó-Vicedo et al., 2007; Lehtinen and Ahola, 2010*).

Fig. 1 . A schematic representation of shipyard supply chain structure



Logistics Performance Indicators

Organizations may have many performance indicators that are often difficult to measure and monitor. Therefore, selecting a subset of indicators called Key Performance Indicators (KPI), which are representative and may be measured with relative ease and reasonable cost is recommended (*Hausman, 2005*). The KPIs of the organization (or supply chain, in this case) should be carefully selected considering strategic planning, available resources (human, financial, technological, etc.,), and market conditions (*Gunasekaran et al., 2001*).

Normally, performance indicators are classified as qualitative and quantitative. Qualitative performance indicators are those for which there is no direct numerical measurement, although some aspects can be quantified. The following indicators, among others, fall within this category (*Chan et al., 2003*):

- ***Customer satisfaction:*** degree to which customers are satisfied with product or service received.
- ***Flexibility:*** ability of the supply chain to respond to random fluctuations in demand patterns.
- ***Integration of materials and information flows:*** degree to which all functions in the supply chain may exchange information and materials without drawbacks.
- ***Effective risk management:*** the extent to which the effects of risks are minimied.
- ***Supplier performance:*** measuring the performance of raw material suppliers in terms of quality and delivery time.

Quantitative performance indicators may be directly measured in numerical form. They are also sub-divided into four classes (*Nyhuis, 2007*):

- ***Cost and financial indicators:*** cost of entire supply chain, sales levels, profits, inventory investment, return on investment.
- ***Customer response indicators:*** compliance rate, percentage of late deliveries, customer response time, and order time.
- ***Performance indicators:*** capacity utilization, use of resources.
- ***Quality indicators:*** measure the effectiveness of the implementation of activities or processes, providing results on the number of errors, as well as perfect and error-free deliveries.

BSC and Performance Measurement

Monitoring, measurement, analysis, and improvement of corporate strategy require using appropriate tools that reflect the reality in the deployment of that strategy, both internally and in interaction with the other members of the supply chain. Various methods to evaluate supply chain performance and organizations have been proposed over the years; however, most do not have a balanced approach and focus on financial indicators, b they are not suitable for new generations of applications in supply chain management.

The need for performance measurement tools at different levels of decision making and a balanced approach led Kaplan and Norton (1992) to propose the BSC as a means to evaluate the performance of an organization from four different perspectives: customer, financial, internal processes, and learning and growth.

Originally, te BSC concept was essentially a measuring tool. It then evolved into a comprehensive strategic implementation tool. Today, BSC is a performance management system that aligns and focuses organization efforts and resources, using performance indicators to drive strategies and create long-term value. BSC application in supply chain management is structurally similar to the traditional model of corporate management; the difference is that the indicators must be designed to fully evaluate supply chain performance and not only intra-organizational level.

Fuzzy Logic and Performance Measurement

Information lack and information excess create uncertainty and imprecision. Due to growing availability of qualitative information for performance measurement is more practical and easy to measure supply chain performance in linguistic terms, including vagueness concept (*Wang, 2010*). Therefore, performance measurement becomes an important area for fuzzy set theory application incorporating quantitative and qualitative measurements (*Ammar and Wright, 2000*).

Fuzzy logic is a multivariate logic allowing a more practical way to address problems as they occur in the real world. It originates from the fuzzy sets theory proposed by Zadeh (1975), which represents a generalization of the classical sets theory and applies to concepts that can take any truth value in a set of values ranging between absolute truth and total lie. The fuzzy sets foundation is the fact that the building blocks of human reasoning are not numbers but linguistic labels; thereby, fuzzy logic emulates this feature and uses approximate data to find precise solutions.

The fuzzy-set theory strength lies in its ability to provide an alternative framework to modeling imprecision. This allows looking at the vague and possibility concepts separated from the random or probabilistic uncertainty (*Klir and Yuan, 1995*). A fuzzy set is defined by a function that varies between 0 (false) and 1 (true), which assigns the membership degree of each element in a set. The shape of the membership function can be linear (triangular or trapezoidal) or nonlinear (Gaussian, generalized Bell, sigmoid, gamma, etc.,) depending on the nature of the system studied (*Kaufmann and Gil, 1993*). The membership degree represents the degree to which expert opinion places an item in the set. An element can belong to more than one set with different membership degrees, allowing gradual transition between adjacent sets.

Fuzzy BSC Model to Measure Shipyard Supply Chain Performance

In the BSC traditional formulation, the variables are represented by using numerical values and ignoring the fact that, in practice, they are affected by imprecision and vagueness and need to incorporate, in many cases, qualitative variables in measuring performance, hindering mathematical modeling to obtain a specific result to facilitate decision making. To solve this problem and incorporate uncertainty and approximate reasoning in real applications to measure performance in the supply chain studied, a fuzzy logic model is integrated onto the BSC methodology.

The proposed Fuzzy BSC Model has two major components: a knowledge-based and fuzzy processor (Fig. 2). The selection of indicators requires a preliminary stage of literature review and/or consultation with experts on BSC implementation in measuring supply-chain performance and appropriate fuzzy logic models, followed by a stage of contextualization and benchmarking with industry to determine acceptance levels that will serve as input to construct the fuzzy sets and associated membership function with each indicator and then construct the fuzzy rule base necessary for fuzzy processor.

The selected indicators and membership function values are combined in each perspective by using the fuzzy rule base, which contains the set of IF-THEN rules developed from experience and knowledge of a Performance Measurement Team, consisting of personnel from all areas of the organization with training and experience in the field. The Fuzzy Inference System combines the performance levels of the indicators obtained as output of each rule as a single fuzzy output. Defuzzification of the output obtains a crisp number as supply-chain performance indicator.

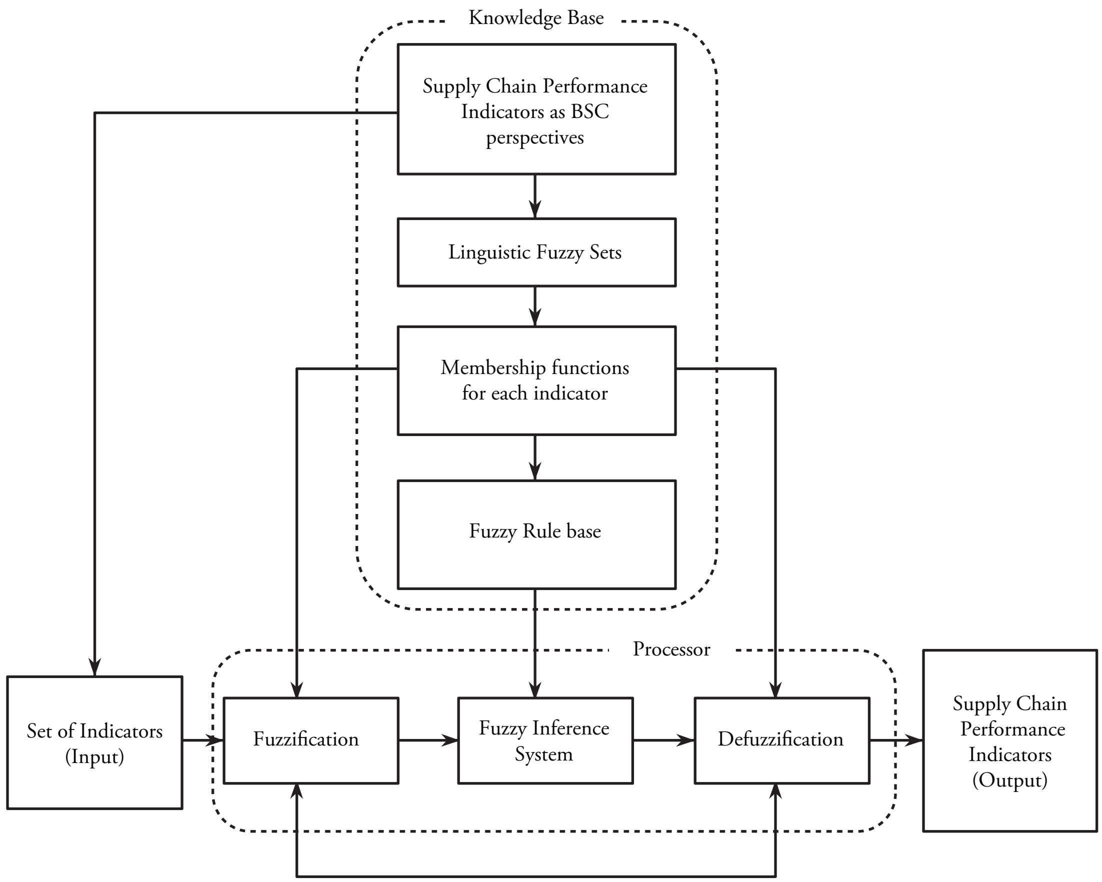
Fuzzy BSC Model Application

The application of the Fuzzy BSC Model was carried out by following the steps: selection of indicators, definition of fuzzy inference method, design of the fuzzy rules system, and defuzzification.

Selection of indicators

The selection of appropriate performance indicators to measure shipyard supply-chain performance is a critical step in the Fuzzy BSC Model application due to the complexity of business

Fig. 2 . Fuzzy BSC Model for supply-chain performance measurement



in this industry: large number of players (many suppliers, Classification Societies, Salvage or Tug Companies, contractors, government entities, etc.) that influence the development of operations, unique design phases, and different manufacturing and delivery times for each product. The indicators selected for the Fuzzy BSC Model to measure the performance of the shipyard supply chain studied are shown in Table 1.

Fuzzy Inference Method

A fuzzy inference method allows deriving conclusions (fuzzy value) from IF-THEN rules set and input-values set to the system by applying the composition ratios. The two most important methods of inference are the Mandani-type model, the most commonly used and introduced by Mandani and Assilian (1975), and the Takagi-Sugeno-Kang (TSK) model proposed by Sugeno and Takagi (1985). The main difference between these two methods is the type of consequence in fuzzy rules. While the Mandani systems use fuzzy sets as a consequence of the rule, the TSK systems employ linear functions of input variables. In this paper, the Mandani-type inference system is used because its outputs are continuous values, while the TSK systems are discrete data.

Fuzzy Inference Rules

The definition of the rules is the most important stage in the design of the Fuzzy BSC Model as embodying the opinion of experts and/or analysis of historical information. This model contains four rule sets for the perspectives and one rule set for global supply-chain performance indicator. The construction of the rules system was made by developing a conclusions matrix by considering all possible combinations of inputs and assigning a conclusion to each.

Table 1 . Set of indicators to measure shipyard supply-chain performance by using the Fuzzy BSC Model

Perspective	No	Indicators	Units
Customer	1	New customer sales	Percentage
	2	Customer satisfaction	Percentage
	3	Sales Compliance	Percentage
Financial	4	Operating margin	Percentage
	5	Fixed-Asset Turnover	Times
	6	EVA	$
Internal Process	7	Cost of warehouse space	$/space
	8	Order rejection rate	Percentage
	9	Inventory turnover	Times
	10	Main assets turnover	CGT/ (m^2.m.Ton)
Learning and Growth	11	Employee turnover	Percentage
	12	R&D/Sales investment	Percentage
	13	Corporate Governance Compliance	Percentage

Customer perspective, for example, is evaluated in three input variables (new customers sales, customer satisfaction and sales compliance), which have three fuzzy categories (low, medium and high); therefore, there are 33 = 27 possible combinations in the matrix of definition of fuzzy rules (Table 2). Values in the cells represent the consequence of describing each combination and correspond to the linguistic categories or labels of fuzzy subsets of the output variable, and "L" corresponds to low, "ML" is medium-low, "S" is standard, "MH" is medium to high, and "H" is high. These labels apply to the definition of rules in the remaining four rule sets.

Any cell in Table 2 may be expressed as a rule. For example, the shaded cell corresponds to the following rule: IF sales compliance is *medium* and customer satisfaction is *low* and new customers sales is *low*, THEN customer perspective is *low*.

Table 2 . Fuzzy rules matrix of customer perspective

Sales Compliance											
Low				Medium				High			
New costumer sales	Costumer Satisfaction			New costumer sales	Costumer Satisfaction			New costumer sales	Costumer Satisfaction		
	Low	Medium	High		Low	Medium	High		Low	Medium	High
Low	L	L	L	Low	L	ML	ML	Low	S	S	MH
Medium	L	L	L	Medium	ML	S	S	Medium	S	MH	H
High	L	L	ML	High	MH	MH	MH	High	MH	H	H

Defuzzification

The result of the inference process is a set with a fuzzy distribution as response. However, because generally specific responses are used to facilitate decision making, it is necessary to remove the fuzziness to obtain a crisp number. The literature describes various methods to eliminate fuzziness as the center of the area, bisecting the area, smaller than maximum or larger than maximum (*Jang et al., 1997*). The appropriate method depends on its degree of adjustment to considerations and constraints of the application.

The center-of-area method is one of the most commonly used and was used in this study because of its continuity and because it calculates the overlap area only once, unlike other methods. The specific value of the performance indicators for each perspective and global supply-chain performance indicator were generated by finding the center of gravity of the membership function of respective fuzzy outputs. Analytical development and calculations were performed by using the Matlab© Fuzzy Toolbox.

Global Supply-Chain Performance Indicator

The computational results of applying the Fuzzy BSC Model for shipyard supply-chain performance measurement are shown in Figure 3. The BSC perspective indicator results (Customer = 75%, Financial = 85%, Internal process = 78%, and Learning and Growth = 92%) and global shipyard supply-chain performance indicator (75.9%) may be interpreted as the degree to which the supply chain achieves the goals and objectives of supply chain management within each perspective and globally.

Conclusions

Performance measurement is an essential element in planning, control, and decision making of

Fig. 3. Computational results of shipyard supply chain performance measurement using Fuzzy BSC Model

supply and chain management. It is necessary to move towards performance measurements systems that consider interaction with all the links in the chain and go beyond the internal focus that still prevails in most organizations.

Fuzzy logic provides a new approach to modeling the uncertainty that characterizes supply chain management. Furthermore, it is considered easier to apply and adapt compared to conventional approaches, especially when there is a large number of input data.

Modeling indicators using fuzzy logic should not be approached as a way to compare results with classical logic because the former is an extension of the second and there should be no contradiction between the results with either approach. The difference is that fuzzy logic allows for an extension of the information obtained and increased ability to represent vague or uncertain phenomena.

The application of the proposed Fuzzy BSC Model allowed obtaining specific numerical values like BSC perspective indicators and global performance indicators in the supply chain studied. This model has a systematic structure that allows easy adaptation to other supply chain types or other business management problems.

References

ABDUL, A. and NABI, M. The need for a new product development framework for engineer-to-order products. *European Journal of Innovation Management*, 6 (3): 182-196, 2003.

AMMAR, S. and WRIGHT, R. Applying fuzzy-set theory to performance evaluation. *Socio-Economic Planning Sciences*, 34: 285 -302, 2000.

BALLOU, R., GILBERT, S. and MUKHERJEE, A. New Managerial Challenges from Supply Chain Opportunities. *Industrial Marketing Management*, 29: 7-18, 2000.

BEAMON, B. and CHEN, V. Performance analysis of conjoined supply chains. *International Journal of Production Research*, 39 (14): 3195-3218, 2001.

CAPÓ-VICEDO, J., TOMÁS-MIQUEL, J. and EXPÓSITO-LANGA, M. La gestión del conocimiento en la cadena de suministro: Análisis de la influencia del contexto organizativo. *Información Tecnológica*, 18(1): 127-135, 2007.

GOSLING, J. and NAIM, M. Engineer-to-order supply chain management: a literature review and research agenda. *International Journal of Production Economics*, 122: 741-754, 2009.

KANDA, A. and DESHMUKH, S.G. Coordination in supply chains: an evaluation using fuzzy logic. *Production Planning & Control*, 18 (5): 420-435, 2007.

KAUFMANN, A. and GIL, J. *Introducción de la teoría de los subconjuntos borrosos a la gestión de las empresas*. 3 ed. Santiago de Compostela: Milladoiro, 1993. 252 P.

KLIR, G. and YUAN, B. *Fuzzy Sets and Fuzzy Logic: Theory and Application*. New Jersey: Prentice Hall, 1995.

LANCIONI, R. New Developments in Supply Chain Management for the Millennium. *Industrial Marketing Management*, 29: 1-6, 2000.

LAU, H., PANG, W. and WONG, C. Methodology for monitoring supply chain performance: a fuzzy logic approach. *Logistics Information Management*, 15 (4): 271 - 280, 2002.

LEHTINEN, J. and AHOLA, T. Is performance measurement suitable for an extended enterprise?. *International Journal of Operations & Production Management*, 30 (2): 181-204, 2010.

MAMDANI, E.H. and ASSILIAN, S. An experiment in linguistic synthesis with a fuzzy logic controller. *International Journal of Man-Machine Studies*, 7(1): 1-13, 1975.

LING, CH., CHIU, H. and TSENG, Y. Agility evaluation using fuzzy logic. *International Journal of Production Economics*, 101: 353 - 368, 2006.

OHDAR, R. and KUMAR, P. Performance measurement and evaluation of suppliers in supply chain: an evolutionary fuzzy-based approach. *Journal of Manufacturing Technology Management*, 15 (8): 723 - 734, 2004.

OLHAGER, J. Strategic positioning of the order penetration point. *International Journal of Production Economics*, 85 (3): 319-329, 2003.

SILVA, C., SOUSA, J. and RUNKLER, T. Optimization of logistic systems using fuzzy weighted aggregation. *Fuzzy Sets and Systems*, 158: 1947 - 1960, 2007.

SUGENO, M. and TAKAGI, T. Fuzzy identification of systems and its application to modeling and control. *IEEE Trans. Syst. Man and Cybern.*, 15: 116-132, 1985.

WANG, W. A fuzzy linguistic computing approach to supplier evaluation. *Applied Mathematical Modeling*, 34: 3130 - 3141, 2010.

ZADEH, L. Fuzzy Sets and their applications to cognitive and decision processes. London: Academic Press, 1975.

New technological surveillance and benchmarking theories and tools applied to sustainable and strategic planning of the naval industry

Aplicación de la Inteligencia Competitiva y el Benchmarking de nuevas teorías para el desarrollo de un Plan Estratégico y Sostenible para la Industria Naval

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Abstract

Since their beginning, companies establish procedures to observe their competitors. Methods for obtaining this kind of information have evolved with the internet era; a plethora of tools is nowadays available for this job. As a consequence, a new problem has emerged: documentary noise, keeping companies from being able to process and benefit from the huge amount of information gathered. Strategic planning mainly relies on obtaining environmental knowledge, so companies need help on dealing with this documentary noise; technological surveillance and benchmarking are preferred methodologies to achieve this objective, coping with data produced by automatic internet tools like search engines and others. Qualified results of better nature are produced by bringing new theories on information gathering and processing into both tools. This article exposes empirical results on the application of a demonstrative technological surveillance system based on different R&D management structures, relying on benchmarking indicators for the naval and aeronautics industries.

Key words: Technological surveillance, benchmarking, neural networks, internet, strategic planning, technological indicators, market intelligence, trackers, indexers, feeders, decision structures, search engines, semantic web.

Resumen

Desde su inicio, las empresas establecen procedimientos para observar a sus competidores. Los métodos para obtener este tipo de información han evolucionado con la era del internet; una gran cantidad de herramientas está disponible en la actualidad para esta tarea. En consecuencia, ha surgido un nuevo problema: ruido documental, que evita que las empresas procesen y se beneficien de la gran cantidad de información recolectada. La planeación estratégica principalmente se apoya en el conocimiento ambiental obtenido, así que las empresas necesitan ayuda para tratar con este ruido documental; la vigilancia tecnológica y el benchmarking son metodologías preferidas para lograr este objetivo, y hacer frente a los datos producidos por herramientas automáticas del internet como motores de búsqueda y otras. Este artículo expone resultados empíricos acerca de la aplicación de un sistema demostrativo de vigilancia tecnológica basado en diferentes estructuras de gestión de I&D, confiando en indicadores de *benchmarking* para las industrias navales y aeronáuticas.

Palabras claves: Vigilancia tecnológica, *benchmarking*, redes neuronales, internet, planeación estratégica, indicadores tecnológicos, inteligencia de mercado, seguidores, indizadores, alimentadores, estructuras de decisión, motores de búsqueda, web semántica.

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Introduction

We live in a complex society, both on the social side and in the business arena. Every aspect of daily work builds on the actual lines that every company, from every sector of activity, follows to succeed in achieving its strategic objectives. The naval sector, with a significant share in national economies is no exception. Until now, the main research on corporate structures in sectors such as the naval industry, have focused on its manufacturing systems and control [1].

The basis and relationships that enable good practices in business management can be modeled over two classical dichotomies, the internal/external point of views and the knowledge/know-how levels on the technical plane. The first expresses the need for contrast, where the internal procedures governed by a set of rules and practices confront against what others do and develop; the second shows how a company can differentiate from competitors, on technology or expertise, with none of the two not necessarily being the best; all these actions pursue new improvements to be consistently brought into the organization. Technological Surveillance (TS) [2] and Benchmarking (BM) are two of the most widely used methodologies to help companies to review their own organizational structures and technology, and their commitment to the company mission. History shows that companies have been looking into and comparing what competitors do since their creation; non-directed, casual or other non-organized manners are usual, even the use of existing tools that, logically, are not fully adjusted to the particular needs of each company. TS and BM are complementary methodologies and a comprehensive plethora of supporting tools are available, which allow companies to evaluate their capabilities and to outline strategic actions on the mission of achieving a privileged market position; innovation projects and research and development (R&D) activities are perfect instruments for this task.

"Technological surveillance" systems in the case of Naval Engineering will be formed from four dimensions [2]: i) Technology, the responsibility lies with the director of production, ii) Commercial, with responsibility split among the sales director, marketing, and exploitation; iii) Competitive, for which the commercial director is responsible, and iv) Socio-Economic, under the responsibility of the administrator and quality Manager).

In the case of naval engineering, technological surveillance focuses on nine areas [2]: i) Material; ii) Joining technologies and processes; iii) Marine corrosion; iv) Surface treatment; v) recycling technology vi) Improved manufacturing technologies; vii) Application of information and communication technologies vii) techniques applied to repair work, re-use, and scrapping; ix) Environmental management applied to the naval industry.

Additionally, knowledge and innovation management systems that organizations deploy are of great importance to accomplish the task of building sound strategic plans. Currently, the largest database for knowledge and innovation is on the Internet, but this information is scattered; millions of data alone do not have strategic value and, therefore, require new strategies and techniques to convert data knowledge.

Several theoretical models exist that try to explain and to settle down the structure and functioning of the innovation and knowledge paths and mechanisms for any kind of organization or enterprise. In this article, we explore three of them, the linear model, the Marquis model and the Kline model. The three are commonplace in companies nowadays and other research and development organizations, and depending on the complexity of their R&D, innovation and knowledge management systems, a best-fit model can be applied. The Linear model is the simplest one; it does not take into account feedback paths and it is fully sequential; it is far from current R&D structures, and only traditionally managed centers, mainly ones with academic activity, can be modeled this way. The Marquis model is a more advanced approach to current systems, and it is powerful enough to model young companies or others with simple management systems in this area; knowledge and innovation management systems largely in use include feedback processes and some links between earlier and later stages of the innovation process. The last model considered, the Kline model, is the most complete of the three; it is built on the principle that there are three relevant areas in the technological innovation process, briefly: research, knowledge, and innovation. These areas are connected by means of innovation paths, and there is a main path, known as the central innovation chain [3].

Currently, there are clear examples of companies using Competitive Intelligence and Technological surveillance to increase their productivity and competitiveness, among them we can highlight the Naval Sector Cluster Gallego (ACLUNAGA) created via the initiative of the Department of Industry and Trade of the *Xunta de Galicia* to become the meeting point of all naval officers and the maritime industry of Galicia. ACLUNGA's mission is to promote a new form of company management based on cooperation, focusing on core business, and one of the main aims is to promote innovation to add more value to the product in all stages of development, promoting R&D and strengthening the technological infrastructure with a State Technological Surveillance (TS) and Competitive Intelligence (CI) [4].

This article presents the empirical results of applying a Technological Surveillance demonstration system, focused on diverse organizational structures for R&D management, which rely on indicators from Benchmarking processes between the naval and aeronautics industries. These indicators are extracted by new tools and methods for information processing.

This introduction presents the context of the work; the rest of the article is structured into four main blocks, along with final conclusions and references. The first block describes the benchmarking methodologies, their advantages and handicaps, and the innovative approach taken for their use towards an efficient method for strategic information processing. The second block describes technological surveillance methods and their application to strategic planning; problems raised by new internet tools are noted and solutions proposed. The third block describes knowledge and innovation management system models and their application to better analyze and solve the problems noted. The fourth block addresses the study case of the article, where the methodologies and models described are jointly used to analyze the naval and aeronautics industries; results are presented.

Benchmarking methodologies for strategic planning

Benchmarking methodologies focus on comparison procedures. These procedures include several players or partners to compare with, from whom you gather information and evaluate several business aspects in a unified manner so that results can be easily confronted against other participants' results. Additionally, there are several sensitive aspects to deal with, such as the treatment of confidential data, "only for internal use" issues, or other non-shareable information. These issues are normally dealt with by means of some anonymous procedures, like data aggregation, confidential treatment of names, or even building a model against which companies compare to, not to the actual data of others.

One of the most important premises that yield the best benchmarking results is to select a group of companies that fulfill at least good similarity criteria; notwithstanding, being also quite divergent on their achievements and structures, as one of the fundamental abilities to manage all information collected through an appropriate ICT environment, allowing us to control the its entire life cycle [5]. Usually, best-of-class companies from the same sector are chosen; thus, both directions are covered, but the view obtained still lacks a holistic approach. In this article, we have tried to enhance diversity by merging two sectors that can be seen similarly, the naval and aeronautics sectors. Both share a common industrial vision and technology issues can also be considered in parallel manner.

Benchmarking effectiveness relies on a good selection of the comparison criteria, which should be comprehensive, adapted for structure description, easily evaluated and transversal to all participants. Thereby, criteria selection also drives the identification of adequate indicators; this selection is then a way to perform identification while accomplishing the best commitment for the indicators. Some methodologies have been proposed for the benchmarking studies [6], they benefit from other techniques like balanced scorecard, and from this perspective, useful benchmark measures are those that best represent the critical success factors for the sector as a whole. Continuing with the description of new theories for technological capability enhancement, applicable in the naval sector, we can divide these capabilities into acquisitive, operative, predictive, creative, and marketing, which map directly into the usual structure of any industrial company and most service enterprises. Methodologies focus on added value in a staged process that usually follows five main steps: self-awareness of the organization, identification of value added areas, needed technological capabilities, classical benchmarking (indicators, evaluation and comparison against a reference), and analysis and diagnosis. A clear example of how the Internet can help generate new knowledge and value in the naval industry can be seen in the research for this for "hemorrhage control" [7].

Some research [8] is also underway on the application of Neural Networks (NN), Fuzzy Logic (FL), Genetic Algorithms (GA), and Particle Swarm (PS) methods for business optimization. The use of NN techniques allows modeling business results as the output of a learning process based on key company variables (economic factors, level of staff training, competitiveness, research and development). Also, PS can simulate the benchmarking processes that companies use continuously to enhance their market performance and evolve over time.

Other approaches [9] focus on the evolving relationship of the two factors that drive a company's products or services, customer needs, and competitor performance. Terms like quality, cost, functionality and even technology change over time and most product design processes do not invest enough efforts on taking care of their evolution. Forecasting techniques and benchmarking information drive the gaining of competitive advantage for companies that use dynamic models to improve their processes, integrating the results into their strategic plans.

In this article, we consider that all these approaches to the benchmarking process target specific issues that must be cared for, and we show that one of the key points is the adequate identification of evaluation criteria and correct selection of useful indicators. The naval industry carries out benchmarking studies from time to time [10, 11]; these studies cover issues on the main levels of business strategic and organizational development and also benchmark specific technical areas that build up the technological background of the sector.

We can extract a common benchmarking layout from several studies carried out during the past few years in the naval sector. This exercise leads to our focus in this article, the sensitive analysis of data collected. The US Navy's 10-step process [12] has served as a guide for some of them; also, its proposal can be comprehensively adapted to the aeronautics sector as it gathers the best practices from other BM methods used by consultancy companies and main players in the field. Nevertheless, we cannot oversee the main differences between both sectors (setting the defense area aside), which are cargo-oriented applications in the naval sector vs. passenger transportation in the aeronautics sector; the technological maturity of each one and the environmental issues that affect each sector differently, along with the exploitation of vessels and airplanes differs on several aspects although being quite similar in the general operation structure when cargo vs. passenger issues are dealt with. We propose using the new information processing methods to delve into the analysis stages, were effectiveness is more sensitive and improvements offer best returns on results.

Nonetheless, as mentioned before, technological surveillance is the other tool for building a sustainable and consistent strategy for the naval industry. We describe the proposed approach in the following paragraphs.

Technological surveillance for strategic planning

The technological aspects that strategic planning must consider are the target for the technological surveillance methodologies. With the emergence of internet, the access to information sources has become a common place to look for innovation news and competitors' advances; TS is the method for organizing, applying selectiveness, and converting external information into knowledge to make less risky decisions and anticipate changes. Watching available technologies or emerging ones and analyzing whether they are able to take part within the products or processes of the company is the needed task, which is not always adequately performed. What must be watched are the scientific and technological advances, products and services, manufacturing processes, new materials and their transforming chain, information technologies, etc., and an applicability assessment must also be carried out on the information gathered; this assessment is the most sensitive step. Thus, potential lines of interest are detected and can be conveniently brought into the organization's value resources.

The current tools for TS on the internet have reached a so-called second generation. First generation tools are the classical search engines and directory and index navigators, they have some limitations like incomplete coverage (invisible internet) and poorly advanced search options, which may produce the so-called documentary noise and silences, but on the other hand, they are precise because end sources are always reached. These tools have evolved into more powerful solutions by integrating automation, programming capabilities, and customization; this evolution is driven by a trend to seek for information quality more than for information quantity.

This second generation comprises tools like multi-search engines, extracting tools, feeders, visits analysis, website dumpers, website surveillance, markers, agents, mapping tools, and access to deep internet. Deep internet comprises online not directly accessible resources like data bases, catalogs, dictionaries, statistical reports, numerical and text information, formatted documents, multimedia files, self-excluded web sites, password-protected web sites, as well as the results offered by less-strict matching criteria ("like", "related" matching). The tools of this second-generation oriented semantic analysis of the information and knowledge extraction for raising business competitiveness can be highlighted:

- Swoogle [13, 14]: A system of indexing and retrieval for the Semantic Web documents, i.e., a Google for the Semantic Web, though not yet brought to the end user, who seeks, and even classifies documents and valid measures, monitors and analyzes vocabularies semantic Web or ontology.
- CORESE [15, 16]: Conceptual Resource Search Engine (CORESE) is an engine that enables processing RDFS, OWL, and RDF instructions. The main functionality of the tool is designed to retrieve Web resources annotated in RDF, using a query language based Query Language for RDF, SPARQL, and an inference rules engine.
- WebKB [17]: This tool has an online interface that allows sentences through creating or sharing specialized knowledge base. The knowledge base was initialized with the contents of the WordNet lexical database, without taking into account the information about verbs, adverbs and adjectives. Includes ontologies as part of a knowledge base, defined as a list of categories and formal statements that give meaning to the category. Xiaoguang [18] can be seen in a comparison table of this tool with others, are best used when analyzing each.
- Kartoo [19, 20]: It is the first free search engine that personalizes results based on user interest centers while allowing you to manage and monitor information available online.
- Hakia [21, 22]: It is a concept whose semantic search engine is very different from other search engines. In a way, it could be defined as an anti-seo search engine, as are its search results from those positioned on search engines and classic style, but also to give prominence to the page content, dive-in content semantics. It seeks to overcome the biggest problem that search engines crawl: its spiders are blind. Hakia tries to improve Google's approach and

uses semantic technology that gives greater prominence to the results, in turn favored by the "library" that cooperates to recommend reliable sources of information.
- Factbites: It is a semantic search engine developed by the Australian company, Rapid Intelligence, whose philosophy is to provide meaningful results. It also generates meaningful sentences that summarize the main content of each result. For all uses of computational linguistics, data mining, data storage, and artificial intelligence.

During this second generation, things have evolved from inputting and querying data into seeking knowledge within the data. This new generation has been named as the "Age of Knowledge", and its main features are that, i) it allows the extraction of raw data from Internet using "crawlers", and that, ii) it allows the further processing of these data using "business intelligence" techniques, which will lead to knowledge. That knowledge turns into a competitive advantage for those companies able to use it.

There is lots of information not able to be indexed by standard web spiders from classical search engines; this information is located behind documentation services, data bases, and other repositories that need a special access application. Some efforts were made a few years ago and the Z39.50 standard [23] was revised and evolved until the protocol pair Search & Retrieval via URL/Web Service (SRU/SRW) [24], which kept the original powerful queries and integrated over hypertext transport protocol (http) communications protocol; the original Z39.50 and its derivative protocol pair allow for searching and retrieving information from remote databases, they are widely spread among integrated library systems and bibliographic software. The fact that puts all this kind of information on the deep side of internet is that a client application is required on the user side, setting aside standard search engines. Multi-search engines combine results from several standard search engines so that information throughput is maximized, and also meta-search engines offer enhanced task automation and are extremely configurable so that they can solve specific search and retrieve tasks. Duplicate removal and result classification are among the most usual features that help in the task of managing the huge amount of information that today's internet holds inside.

Web trackers are tools that explore the hypertextual nature of the web; results are obtained by exploring the hypertext tree from an initial site that acts as the seed. Links are tracked and daughter web pages are classified according to their relevance, often with some weighting criteria. Likewise, selected pages' links are tracked and granddaughter pages are again explored, so this process continues until some limiting criteria is reached, usually the exploration time or the depth level of the links. This technique is prone to getting looped and to generating documentary noise, feedback mechanisms on these issues help as a kind of learning process.

Its evolution has brought a highly specialized set of tools that can build up "maps" on the information retrieved. Maps are graphical descriptions of web sites and their contents. Quantitative data are integrated into the maps, providing a high degree of detail. Maps offer a very intuitive view of the relative content of web sites as information is presented in a "geographically" significant manner, showing aggregate information over a two-dimensional representation of the set of sites searched.

A very useful derivative of this is the specific build-up of technology maps, TS methods also include information not only on the technology itself but also where it is being developed (i.e., by which research groups). A well-known application of this kind is the search and mapping of intellectual property; patents are well-documented and are searchable by applications like the Matheo Analyzer [25] and others.

The concepts behind these mapping tools are the object of further research, some work [26] on concept maps and their mining is based on concept extraction tools. The authors referred propose a method based on the use of grammatical parsers and latent semantic analysis, a three-stage procedure is also proposed: Concept Extraction, Relationship Extraction, and Topology Extraction. The method was tested among a selected corpus of essays, providing a good benchmarking basis for the evaluation of the proposed algorithms for concept extraction. Concept Map Mining (CMM) is one of the promising tools that will produce innovative solutions to what the main statement of this article proposes; it has served as the guiding basis for the development of this study, which relates Technological Surveillance to Benchmarking.

All these methods, tools, and applications build up the Technological Surveillance issues needed to assess knowledge on the organizational structure, production processes, research and development, and knowledge management systems that must improve the effectiveness of the inter-sector benchmarking methodology that we propose in this article.

Knowledge and innovation management modeling

Nevertheless, and despite of the known necessity of the Technological Surveillance methods and their transversal application by means of an inter-sector benchmarking, the new technologies for information processing and their increased capability for data mining have created the aforementioned problem on the business intelligence and organizational knowledge management areas, not yet satisfactorily solved: documentary noise and information noise because of the huge amounts of data and the lack of analysis, structuring, modeling, and selection procedures on the information gathered.

In the previous paragraphs, we showed several existing tools and also several techniques that form the basis of current TS tools to obtain primary information. We call primary information that which, despite being analyzed, structured, and cleaned (for example, the search results of an indexer tool), either does not fit the real needs of an entity or does not have the necessary characteristics for being naturally absorbed by the human capital of the organization.

There are multiple references [27] that focus on the models for knowledge management at an entity in a manner that is not related to human capital. They work on the information structure (and by extension on the knowledge structure) to be natural and adequate, and to be accessible and understandable within the organization. However, they do not get deep enough on the dissemination and natural assimilation by the employees, which are not able to keep at the same pace at which it is generated. At most, they consider the issuing of periodic informative bulletins.

When using TS as the basis for the strategic management of an entity, it is not profitable to keep this information stored in a structured manner, nor by communicating it through periodic bulletins. On the contrary, the information must penetrate into the daily employees' activities, to the extent where it is useful. This way, it takes part on the value and tools that the entity provides to its employees to adequately execute their work. A perfect coordination between good management and execution of the organization strategic plan, a profitable TS policy, and a good company knowledge management system must be achieved for all efforts to be efficient and effective in all areas.

In our study case, we have worked on the impact TS has upon the organization, depending on the knowledge management system and on the enforced information distribution policy. The work is presented for TS indicators based on inter-sector benchmarking. The reason is that this type of watching offers a wider range on the impact measurements regarding creativity and work team new knowledge assimilation, and it also offers more evident and measurable indicators targeting an empirical study like this.

For the present study, three types of organizations were selected. They have different structures for the management and integration of R&D processes and, to a certain extent, they fit into the following theoretical models: the Linear model, Marquis model, and Kline model, which we describe hereinafter.

The linear model[1] is based on a classical concept for R&D and innovation, where development is a consequence of research and where innovation is seemingly a consequence of development. This model, despite being the most extended as reference, is also the most distant from reality, given that it does not take into account the market influence over the first stages of the chain. This model does not relate decisions at the research stage (and at the strategic lines development) to the information gathered from the market, competitors, successful innovative results on other sectors, or new technologies. Nowadays, we can find organizations fitting into a near-linear model at the fundamental research arena, which are public or at least they are subsidized, because other organization types would not be sustainable with present business schemes.

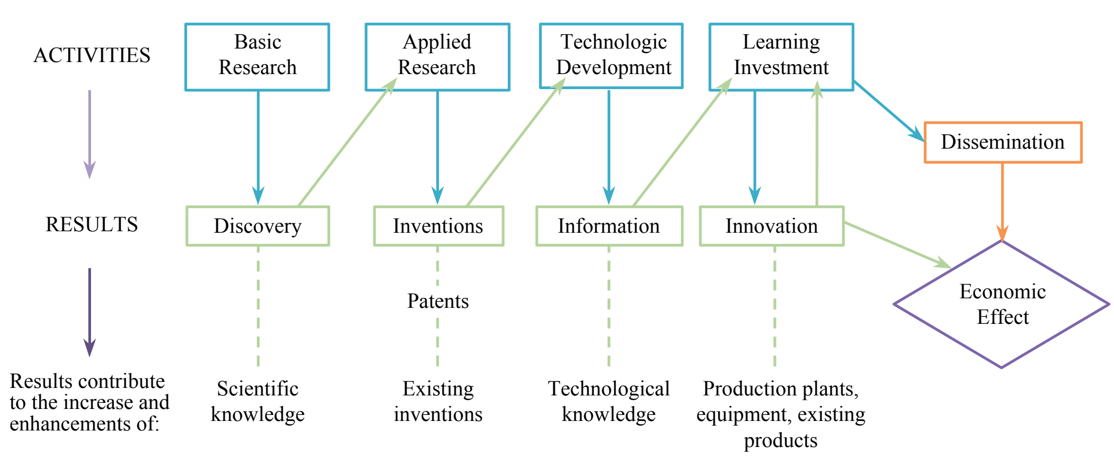
Linear models are the so-called first generation models and, although they have evolved to models based on the "demand pull" instead of only the "technology push", they consider only sequential scenarios, very simplified, to describe innovative processes as currently known [28]. This model will help us to identify some of the relevant indicators for our analysis, as we will describe hereafter.

[1] The precise source of the linear model remains nebulous, having never been documented. Several authors who have used, improved, or criticized the model during the last fifty years have rarely acknowledged or cited any original source. The model was usually taken for granted. According to others, however, it comes directly from V. Bush's "Science: The Endless Frontier" (1945) {Godin, 2005 #26}

The Marquis model [30] is characterized by being the closest to business reality. It considers that innovation, and consequently research (mainly applied research) and development investment, is driven by suppliers (based on new technological offerings) and by the demand (based on social and market needs). To be precise, this model presents a new point of view in the sense that "recognition of demand is a more frequent factor in successful innovation than recognition of technical potential" [30]. Actually, the Marquis model constitutes a mixed third-generation model, where elements like technology push and demand pull are included. It also takes into account the interaction between the technological capabilities on one side and the market needs on the other, also including the feedback processes generated among the different innovation stages [28]. Second-generation models have not been considered for this study given that they do not contribute with a differential value to the analysis done because they are just staged sequential models.

The Marquis model, despite the years passed and the controversial discussions at its beginnings, is one of the best adapted to the vertiginous world of Information and Communications Technologies (ICT) and to the Information Society (IS), where it is frequent that part of the end users is ahead in needs or even leads trends. A clear example of this phenomenon is that arising from the so-called "*de facto*" standards born from the Internet Engineering Task Force (IETF) and from the

Fig. 1. Linear model for innovation



Source: Rosseger, 1980 [29]

more advanced internauts of the closing years of the 20th century. Another example of demand-pulled innovations are the innovations that end users propose by themselves. Eric von Hippel [31], a professor at MIT, studied in depth the innovations produced by lead users, whom he considers a remarkable source of innovation because they anticipate market trends and also because they have the knowledge and incentives to develop solutions on their own. For this reason, companies can benefit from the systematic study of pioneer users and their activities. As can be observed, this model is an evolution from linear models that includes interactions and feedback among stages.

We must remark some characteristics of the Marquis model for a better context settling of our study, they are:

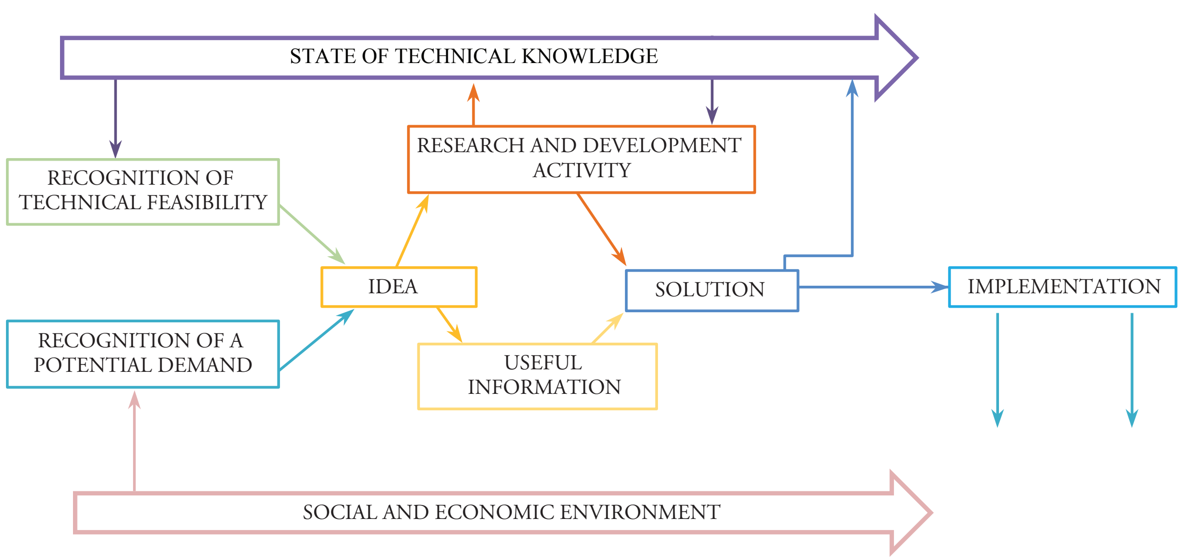
- The fundamental requirements for any idea to progress are the technical achievability and the potential demand, so that if no application or end target is detected this line does not continue. To summarize, directing lines and, thus, the technological evolution of any organization are led mainly by the market and technical state-of-the-art.
- The relevant stages of technological maturity achievement of entities that adhere to this model are:

  - Conceptualization of the idea: involves technical feasibility and market demand, and the evaluation of the needs for research or innovation.
  - Prototype or pilot plants build-up: on the purpose of acquiring technological and economic knowledge applicable to the market development of the idea.
  - Design, manufacture, marketing and introduction into market: linked to the rendering of the R&D investment; although scarcely considered so, it is the most expensive stage.

The third model (Kline) [3] presented as reference for this study is the most complete, complex, and versatile of the three. In fact, it includes the greatest set of R&D and innovation management conceptualization parameters in use nowadays. Although it is considered a third-generation model (most evolved models are fifth-generation, networked models), it sets the basis for the evolution of the fourth- and fifth-generation models as it includes indicators and flexible relationships among the different chain steps. In fact, it is called the chain model.

The Kline model considers that there are three areas of relevance in the technological innovation

Fig. 2. The Marquis model for innovation



Source: from contributions by Gruber & Marquis, 1969 [32]; Myers & Marquis, 1969 [33]; Marquis, 1969 [34]; Utterback, 1969 [35], 1971a [36], 1971b [37].

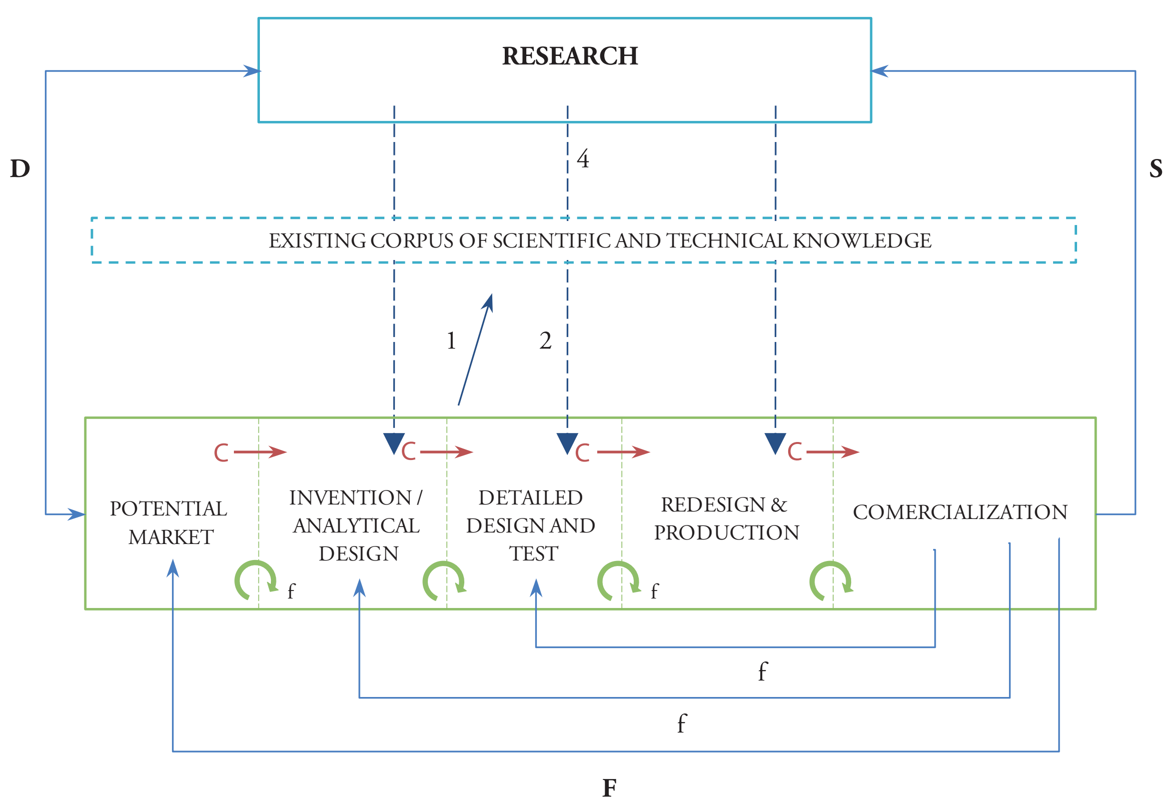
process: research, knowledge, and the innovation process itself. These areas can be interconnected by different paths or innovation processes. The first path, called central innovation chain [3], begins with an idea that builds-up into an invention or analytical design (engineering design) and that reacts to a market need. It is represented by C arrows.

The second path consists of a series of feedback links and other paths among steps that we describe herein:

- f and F: feedback links. Deficiency correction, enhancements, adaptation to newly arisen market needs, etc.
- Arrows 1-2 and 3-4. Link to research through the use of knowledge. Research is not the usual source for innovations.
- D: Link between research and innovation. Research results and discoveries that come into inventions (technology push), i.e., on some occasions, new scientific discoveries enable radical innovations [3] page 293. Link is bidirectional, although science creates opportunities for new products, the perception of needs or possible market advantages can also stimulate important research [39] page 77.
- S: Science dependency on technology. Technological advances push deeper and more complex research.

Although this model has been criticized, the flexibility on the interpretation for the modeling of diverse scenarios makes it a very good tool for the empirical analysis of the innovation processes. In fact, as we will see, only small conceptual modifications, or just modifying the application scope, are needed to achieve fourth-generation models (integrated models: with the addition of pipelined, concurrent or simultaneous processes, not only linear ones [40]) and fifth-generation models (where it is considered that learning takes place inside and among companies, and innovation is suggested as a network-distributed process).

Fig. 3. The Kline model for innovation



Source: : Kline, 1985 [38]

Study case

To execute the present study, several entities and organizations have been studied; they present different knowledge and innovation management systems, with different evolution and deployment levels. Precisely, they have been: Public Research Centers (academic research groups and a technological center depending on a public university), private companies with different maturity levels regarding innovations and European technological centers (both public and private, and several of them organized and managed as a networked structured center).

The study was carried out at a benchmarking framework of potential areas in the transportation sector, with a special focus on the naval, railway, and aeronautics sectors; although, only naval and aeronautics results are presented herein. Specifically, and due to synergies among the technological areas, the study paid special attention to new and composite materials, communications and embedded electronic systems and new trends (i.e., photonics), sustainability and energy efficiency, habitability and hygiene, and new energy sources.
Logically, none of the participating organizations fits into a particular model among those previously described. However, they are closer to a certain degree to one of them, as we can see:

- The Linear model: formed mainly by university research groups with academic tradition, whose main characteristic is that their sustainability is achieved by their teaching activities. Their scientific excellence is far from the business reality and it is closer to fundamental research (*i.e.*, materials science) or to the production of reference regulations and standards (*i.e.*, participants International Telecommunications Union (ITU)'s Motion Picture Expert Group (MPEG) working groups).
- The Marquis model: this model is closer to research groups that maintain approaching policies to private companies and to the productive sector. They usually participate in public-private cooperation projects and in programs issued by universities' technology transfer offices. This model also describes, to a great extent, companies with incipient innovation systems or without an R&D department and with lower capabilities for innovating with their own resources.
- The Kline model: Because of its versatility, this model has been used to model companies with high maturity knowledge and innovation management systems, public and private technological centers (usually with fourth-generation models comprising simultaneity and process concurrency) and networked technological centers (on the evolution path to what is considered fifth-generation models).

To produce the study upon which the present article is based, the following components and tools were used in conjunction with variables to parameterize and model our TS & BM system:

- Tool types used for TS: Feeders based on second-generation tools, multi-search engines and meta-search engines, trackers and mapping tools, gateways to infranet, specialized data bases, libraries, specialized magazines, dumpers and site analysis. Distribution agents like RSS, tag clouds (at desktop or personal space access), email, bulletins, advertisements based on semantic analysis. Structure for active search: parametric search engines, indexers or semantic indexes, tag clouds, natural navigation with temperature grading (concept co-occurrence).
- The BM structure used is based on the Concept Map Mining (CMM) methodology, taking as starting point concepts like inter-sector co-occurrence and taking the most of pre-existent tools on some of the organizations that fitted into the NN models and PS models.
- Information sources: news, corporate sites, specialized websites, infranet (libraries, thesis, reports, analytical information, usenet, etc.), data bases and paid sites (*i.e.*, IEEE http://www.ieee.org, DBK http://www.dbk.es), and technological and market observatories.
- Nature of the information: academic information, reports, R&D papers and articles, specialized data bases (i.e., Thomson Innovation or Derwent World Patent Index), corporate and institutional information, dissemination on specialized websites,

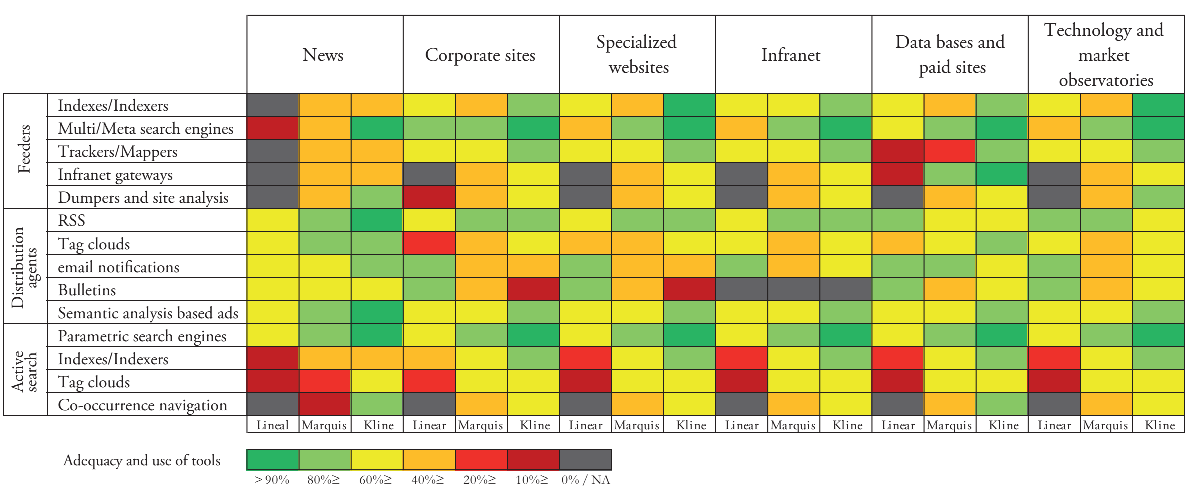
ordinary news, socio-economic environment information
- Organization type and deployed innovation management system: cataloged according to best-fit management model
- Professional profiles: researchers, innovation department (in case it exists, a guiding department, applied R&D and innovation, etc.), product development, production, commercial, communication and marketing, accounting and management.

The main indicators used are:
- Adequacy and use of tools: effective viewing and use of tools (objective criteria: used indicator measurements, subjective criteria: polls) and information validation (objective criteria: increase in documentary quality/work references, subjective criteria: polls)
- Effectiveness of the mechanisms of distribution and sharing of information: information intensity (few, adequate, excessive), adequacy of information for the professional profile and for the individual needs (understanding, use and transformation)
- Increase of knowledge at the organization: clients, suppliers, competitors, state-of-the-art, products or substitute technologies, market trends, and technological foresight (objective criteria: comparative tests, random, single – individual and departmental – on preselected themes, subjective criteria: polls)
- Increase of activities that are creative, productive, innovative, in internal and external cooperation, analytical and of evaluation of market/environment and competition (objective criteria: measurement of indicators on the respective management systems: *i.e.*, ISO 9001, UNE 166000, or R&D and innovation management system, subjective criteria: polls)

The object of this article is not to show the TS & BM results of the organizations involved, which are private and confidential, or to show their individual characterization, but to show the impact of the ute of the aforementioned TS & BM tools in their R&D and innovation management systems. On the following global table, acceptance of the deployment of TS tools over the first months of use is presented. In many cases, these tools already existed, in other cases only periodic bulletin subscriptions or alert subscriptions in specific areas existed. With the exception of some European technological centers, all the subscriptions and data base accesses were widely wasted, but when a more advanced TS system was deployed new forms of information distribution and knowledge generation emerged within these organizations.

This map reflects, in some way, the natural acceptance of employees of TS according to the information type and to the tools used, like at feeders level, and at presentation or distribution

Table 1. Use of tools vs. Information sources



Source: Kline, 1985 [38]

level, or at an active search tools level. During the first month, all the tools were massively used, but during the following months, the use of some tools or others was evidenced based on the type of information, user profiles, type of organization, etc. This map, to a certain degree, presents the starting point that a TS system should provide to these organizations, for their employees to read, process, and assume information in a natural manner.

It should be noted that during the first months of the test, the evolution of the involved organizations, regarding their affinity to a particular model, was clear and evident. Thus, the areas of knowledge related to telecommunications and electronics fitted the Kline model best, and the knowledge areas related to new materials and production processes best fitted the Marquis models. This fact evolved when BM tools were introduced, the differences in knowledge areas were reduced compared to the first situation.

Another important issue to notice is that the use of certain tools depended greatly on the employees' expertise and not only on the organizational structure or on the organizations' knowledge management policy. The evolution of the maps on the use of tools was evident as the months passed and users discovered their usefulness; in fact, in the end the checkered pattern converged into horizontal lines depending on the type of organization.

It is good to notice that, in the organizations with a higher degree of evolution on innovation management, the most accepted and used tools (with both objective and subjective measurements) are those with a greater level of information processing and that show information naturally. The usual media, such as RSS, bulletins, and e-mail notifications were relegated to merely a periodic follow-up, with less acceptance of our target audience (clicks on information entries).

After including BM tools, the effect on the indicators was evident and revealing, even more as the system accumulated more months of use. For the BM inclusion into this study, CMM was used, making relational maps after the concept co-occurrence on the information inputs to the TS system for the selected sectors. Thereby, the input information was already processed information and it came from tools and sources that had been tested during the first months. So the concept analysis was made on the information already processed and, as had been empirically contrasted, this information had a high penetration degree into the organization, both because of its distribution and use and because of its conversion into intrinsic knowledge of the human team. After obtaining the concepts, a "depuration" was conducted by means of summarizing processes (duplicate removal, semantic analysis of the co-occurrence frame, etc.). Afterwards, CMM was applied so that concepts and sources were linked according to their relationship level (jumps between concepts and relationship co-occurrence to a greater or lower degree).

Subsequently, those concepts (or information inputs) that had just one jump of distance to the concept that was searched, indexed or referred by the TS tool were considered valid sources. Likewise, employees were allowed to navigate the relationship branches of the map, so they could make queries in a guided manner due to the relative weights of the possibly related concepts (distance between concepts and co-occurrence of related branches).
The results of applying this CMM methodology, based on NN semantic and co-occurrence analysis, were not evident during the first months; however, the evolution from the third month on was exponential, and the following issues were observed:

- The gradients of the tables of "adequacy and use of tools" presented before became more pronounced, and the knowledge management system reported what it needed (tools, information sources, and information nature) for information to be converted into knowledge within the organization, and later into organizational intelligence in a natural way regarding TS.
- Indicators on creativity and generation of successful ideas grew from 33% to 67%.
- The timing and quality of the economic and technical feasibility analyses at the R&D

and innovation, and production departments improved considerably (source: polls).

- A transition occurred from the use of passive tools of the TS system (bulletins, e-mail alerts, RSS news) to the use of active search tools, even to active parameterization, according to activities or active projects at that moment within the organization. As an example: creation of specific feeders for RSS agents supported on the processed information gathered from active search tools.
- The innovation management models of the organizations tended to change and evolve powered by a phenomena: the communication and inter-relationship among the different chain links and increased knowledge in areas that were not previously known, depending on the department or business unit involved. For example, the dissemination of market information, adequately processed, caused deep impact on the generation of new applied research ideas on R&D departments and groups. The biggest change was observed in the organizations modeled after the Linear model, this was due to the influence of (adequately filtered out and processed) information on clients, competitors, substitutive technologies, market foresights, etc., that broke the linear structure of the R&D and innovation management process. In some instances, the organization evolved to more complex models of innovation management, closer to the business reality and to sustainability issues.

Finally, one of the most interesting results of the study is shown in Table 2, where the results of analyzing the tools used most by each of the profiles analyzed are presented. The adequate information (nature and type) that fitted best on each tool type was obtained from the maps of "adequacy and use of tools", and later, the preference in the use of tools by each professional profile showed the path to choose so that the information was not only adequately analyzed and processed, but also assumed and transformed into knowledge until becoming corporate intelligence.

As with the previous tables, this last one evolved throughout the months, increasing the distribution gradient and naturally identifying the tools that impacted more on each profile and so on the different departments. This fact helped in the build-up of an efficient TS system, which could be deployed based on tools that naturally fit into the knowledge acquisition processes of the employees, therefore, limiting the use of non-optimal tools. Obviously, this fact also limited the information quantity and the documentary noise, which was produced at the turn-on milestone of the TS solution.

The use of BM tools, however, had a lesser impact on the accentuation of the preferred use of certain tools, but it had more impact on the diversification of use of certain tools. We should mentioned the use of dissemination tools or passive search on "semantic analysis-based advertisements", which

Table 2. Use of tools vs. User profiles

		Researchers	Innovation Department	Product development	Production	Commercial	Marketing	Accounting & Management
Feeders	Indexes/Indexers	40%≥	60%≥	80%≥	80%≥	60%≥	> 90%	> 90%
	Multi/Meta search engines	80%≥	> 90%	> 90%	> 90%	80%≥	80%≥	80%≥
	Trackers/Mappers	80%≥	80%≥	60%≥	40%≥	> 90%	60%≥	60%≥
	Infranet gateways	> 90%	80%≥	40%≥	40%≥	0% / NA	0% / NA	0% / NA
	Dumpers and site analysis	20%≥	40%≥	20%≥	10%≥	40%≥	60%≥	10%≥
Distribution agents	RSS	40%≥	40%≥	80%≥	60%≥	80%≥	80%≥	> 90%
	Tag clouds	40%≥	40%≥	20%≥	20%≥	60%≥	40%≥	20%≥
	email notifications	80%≥	20%≥	20%≥	80%≥	40%≥	60%≥	40%≥
	Bulletins	> 90%	10%≥	10%≥	> 90%	40%≥	80%≥	60%≥
	Semantic analysis based ads	80%≥	80%≥	80%≥	80%≥	> 90%	> 90%	80%≥
Active search	Parametric search engines	> 90%	80%≥	> 90%	> 90%	> 90%	> 90%	80%≥
	Indexes/Indexers	40%≥	40%≥	80%≥	80%≥	60%≥	60%≥	> 90%
	Tag clouds	60%≥	60%≥	60%≥	60%≥	60%≥	80%≥	20%≥
	Co-occurrence navigation	> 90%	> 90%	60%≥	60%≥	80%≥	40%≥	60%≥

Use/preference of tools: > 90% | 80%≥ | 60%≥ | 40%≥ | 20%≥ | 10%≥ | 0% / NA

Source: self elaboration

had an important impact on all professional profiles; this constituted a novelty against the already known search engines, which were accepted since the beginning.

Other examples of the diversification of tools are the navigation by co-occurrence on research profiles, innovation department profiles, and commercial profiles. This type of active search had great acceptance for "documentary research" at different areas of organizations. A similar issue happened to tag clouds, which far from becoming a preferred tool, became supporting and backing tools, through which a significant number of clicks were done for the active search of information. Finally, another significant fact that arose was the use of mapping tools and tracking tools for the relational search of technology, clients, providers, etc., that were in fact unexpected and revealing on the R&D, innovation and commercial profiles.

Conclusions

The naval industry is not an exception when TS and BM methodologies come to help in improving R&D and innovation management systems. Both general methodologies are well-known, but the internet has currently raised a new problem: documentary noise produced by new tools for data gathering. Lots of information must be comprehensively processed to be useful for R&D organizations. We have presented the results of the application of new theories to succeed in extracting the best of internet information offerings. Neural Networks and Particle Swarm methods can enhance modeling tools as they are well suited for simulating learning processes and continuous management on R&D and innovation management systems. Strategic planning benefits from sound BM practices, the naval industry has been a perfect sector where BM methods have been employed and even standardized by governments to increase inter-industry cooperation on R&D and innovation management systems aiming to improve sector competitiveness. Also, TS tools have accomplished great development that provides quantity and quality information; several methods on reducing data complexity have been used by organizations involved in this case study, mainly CMM. A natural approach to the best-fitting process of these tools into organizations has been employed to finally produce an optimal R&D and innovation management system for an organization. This is accomplished by modeling R&D management systems according to three classical approaches, the Linear, Marquis, and Kline models for innovation systems. The study reviewed the deployment of TS and BM techniques on several naval and aeronautics R&D organizations (or departments of organizations), it classified them according to the innovation models, and studied the system interactions and evolution according to the rules imposed by the tools.

The results show that TS & BM tools can be very profitable for companies that are still at less-evolved stages on their innovation systems; the tools not only provided them with valuable information, but they also had impact on the evolution of their innovation processes and systems, with improvements on all creativity and innovation production indicators. Their innovation systems evolved into more complex ones, needing more complete models to describe their internal links and effects.

Acknowledgments

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References

1. CHEN, D., G. DOUMEINGTS, AND F. VERNADAT, A*rchitectures for enterprise integration and interoperability: Past, present and future*. Computers in Industry, 2008. 59(7): p. 647-659.

2. DUARTE, F., *Vigilância Tecnológica*, in *Associação das industrias navais*, C.d.e.e.p.e.d.d.I.D.i.n.s. naval, Editor. 2010.

3. KLINE, S. AND N. ROSENBERG, "*An overview of innovation*", in "*The Positive Sum Strategy*". 1986, National Academy Press: Washington.

4. TENA MILLÁN, J. AND A. COMAI, *Inteligencia Competitiva en Empresas Industriales y de Servicio. Experiencia de Implantación en España y Latinoamerica*., ed. E.E.y.P.-R.H.d.l.I. Competitiva. 2006.

5. LEE, S.-S., *et al., Development of internet-based ship technical information management system*. Ocean Engineering, 2006. 33(13): p. 1814-1828.

6. KAPLAN, R.S. AND D.P. NORTON, "*Having trouble with your strategy? Then map it*". Harvard Business Review, 2000(September-October).

7. SNOW, C., C. OLSON, AND T. MELCER, *Navy Medical Technology Watch: Hemostatic Dressing Products for the Battlefield*, N.H.R. Center, Editor. 2009: San Diego, California 92186-5122.

8. BEN ABDELAZIZ, F. AND H. EL-BAZ. "*An optimization model based on Neural Network and Particle Swarm: an application case from de UAE*". in *International Conference on Engineering Systems Management and its Applications (ICESMA)*. 2010. Sharjah: IEEE.

9. RAHARJO, H., *et al.*, "*Dynamic Benchmarking Methodology for Quality Function Deployment*". in *International Conference on Inustrial Engeneering and Enginneering Management (IEEM)*. 2008. Singapore: IEEE.

10. First Marine International, L., *First Marine International Findings for the Global Shipbuilding Industrial Base benchmarking Study*. 2005: London.

11. BROOK, D.A., *et al.*, *Benchmarking Best Practices in Transformation for Sea Enterprise*. 2006, Center for Defense Management Reform.

12. KRAFT, J., "*The Department of the Navy Benchmarking Handbook: A Systems View*". 1997, Department of the Navy.

13. SOREN, A., *et al.*, *Triplify: light-weight linked data publication from relational databases, in Proceedings of the 18th international conference on World wide web*. 2009, ACM: Madrid, Spain.

14. TIM FININ, *et al.*, *Swoogle: Searching for knowledge on the Semantic Web*. American Association for Artificial Intelligence (www.aaai.org), 2005.

15. GAYO, D. *Semantic Browsing of a Domain Specific Resources: The Corese-NeLI Framework*. 2008.

16. CORBY, O., *et al.*, *Ontology-based Approximate Query Processing for Searching the Semantic Web with Corese*. Rapport de recherche nº 5621, 2005. July, 2005.

17. OLIVIER, C., *Searching the Semantic Web: Approximate Query Processing Based on Ontologies*, D.-K. Rose, F.-Z. Catherine, and G. Fabien, Editors. 2006. p. 20-27.

18. XIAOGUANG, Q. AND D.D. BRIAN, *Web page classification: Features and algorithms. ACM Comput*. Surv., 2009. 41(2): p. 1-31.

19. MARCO, A. AND L. BIAGIO, A *web search methodology for different user typologies, in Proceedings of the International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing*. 2009, ACM: Ruse, Bulgaria.

20. WEINBERGER, H., J. FILIPE, AND J. CORDEIRO, *Search in Context Enterprise Information Systems*, W. Aalst, *et al.*, Editors. 2011, Springer Berlin Heidelberg. p. 587-599.

21. BUSSLER, C., *Is Semantic Web Technology Taking the Wrong Turn?* Internet Computing, IEEE, 2008. 12(1): p. 75-79.

22. VANESSA, L., e*t al., Cross ontology query answering on the semantic web: an initial evaluation, in Proceedings of the fifth international conference on Knowledge capture*. 2009, ACM: Redondo Beach, California, USA.

23. ANSI/NISO, *Information Retrieval* (Z39.50): *Application Service Definition and Protocol Specification*. 2003, International Standard Maintenance Agency.

24. SRU/SRW, SRU/SRW (*Search and Retrieve URL/Web Service*).

25. *Matheo Analyzer*: *Database Analysis, Information Mapping*.

26. VILLALON, J. AND R.A. CALVO. "*Concept Extraction from student essays, towards Concept Map Mining*". in *IEEE International Conference on Advanced Learning Technologies 2009*: IEEE Computer Society Washington, DC, USA.

27. ESCORSA CASTELLS, P. AND J. VALLS PASOLA, "*Tecnología e Innovación en la Empresa*". 2005, Barcelona: Alfaomega - Edicions UPC.

28. ROTHWELL, R., "*Towards the fifth-generation innovation process*". International Marketing Review, 1994. 11(1).

29. ROSSEGER, G., "*The Economics of Production and Innovation*". 1980, Oxford: Pergamon Press.

30. MYERS, S. AND D.G. MARQUIS, "*Succesful Industrial Innovations: A Study of Factors Underlying Innovation in Selected Firms*". 1969, National Science Foundation: Washington.

31. VON HIPPEL, E., "T*he sources of Innovation*". 1998: Oxford University Press.

32. GRUBER, W. AND D. MARQUIS, "*Factors in the transfer of Technology*". 1969, Cambridge: MIT Press.

33. MYERS, S. AND D. MARQUIS, "*Successful Commercial Innovations*". 1969, Washington: National Science Foundation.

34. MARQUIS, D., "*The Anatomy of Successful Innovations*". Innovation, 1969. 1(7).

35. UTTERBACK, J.M., "*The process of innovation in instrument firm*". 1969.

36. UTTERBACK, J.M., "*The Process of TYechnological Innovation within the firm*". 1971.

37. UTTERBACK, J.M., "*The process of Innovation: A study of the Origination and Development of ideas for New Scientific Instruments*". IEEE Transactions on Engineering Management", 1971. EM-18(4).

38. KLINE, S.J., "*Innovation is not a linear process*". Research Management, 1985.

39. FERNÁNDEZ SÁNCHEZ, E., "*Innovación, Tecnología y Alianzas Estratégicas*". 1996, Madrid: Editorial Civitas.

40. NONAKA, I. AND H. TAKEUCHI, "*The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*". 1995: Oxford University Press.

Inter-firm cooperation strategies to develop environmental best practices in the Colombian shipyard industry

Estrategias de cooperación inter-empresa para el desarrollo de mejores prácticas medioambientales en la industria de los astilleros colombianos

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Abstract

The present work aims to develop strategies that allow implementingenvironmental best practices inthe Colombian shipyard industry, a sector that has been growing for the last decade and that is identified as a potential world-class industry in the country. Collaborative work was carried out with four of the biggest Colombian shipyards and an international firm to identify legal and operational issues regarding the industrial activity, to reach unified consensus to represent the whole sector. Finally, an environmental best practices document was elaborated to guideshipyard operationsin the country, with the potential to be constituted as an official guide of the Colombian Ministry for the Environment.

Key words: Best practices, environmental management, shipyard, Colombian shipyard industry.

Resumen

El presente trabajo tiene como objetivo desarrollar estrategias que permitan incorporar buenas prácticas ambientales en la industria astillera Colombiana, sector que ha mostrado un crecimiento significativo en la última década y que representa una apuesta productiva para el país. Se efectuó un trabajo colaborativo con cuatro de los astilleros más representativos en el país y una empresa internacional para identificar los aspectos legales y de operación de la actividad industrial que impactan el medio ambiente, de manera que se lograse unificar criterios que tuviesen una representatividad sectorial. Finalmente se consolidó un documento de buenas prácticas ambientales para orientar la operación de astilleros en el país, con el potencial de constituirse como una guía oficial del Ministerio de Ambiente, Vivienda y Desarrollo Territorial colombiano.

Palabras claves: Buenas prácticas, gestión ambiental, astillero, industria astillera Colombiana.

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Introduction

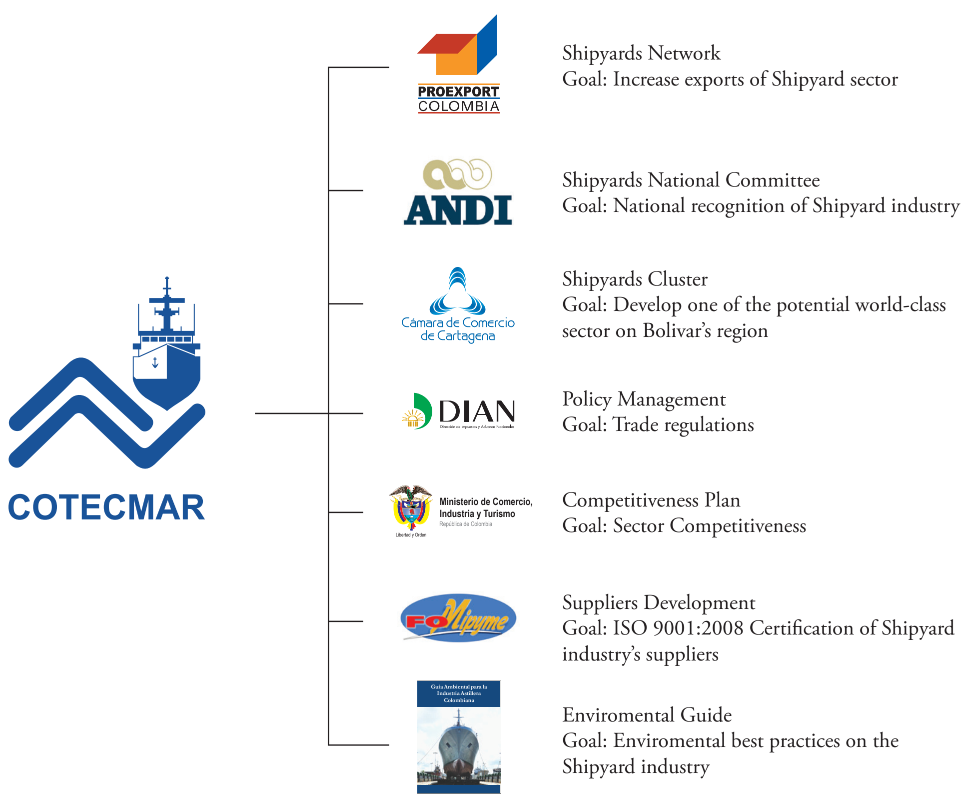
The Colombian shipyard industry represents an emerging sector of the national economy, with significant progress during the last decade that has led to itsestablishment as a strategic sector in the department of Bolívar, one of the principal coastal regions in the country.

Shipyard operations involve a broad range of processes like abrasive blasting and vessel maintenance and materials like Marine Coatings and Antifoulants, which are both especially prone to polluting the surrounding air, water, and soil (*PPRC, 2008*). Shipyards and related industries can significantly impact the environment of many coastal cities.Based on this, it is important to develop Environmental Best Practices (EBP) in the industry, parallel to technological and economic growth, to manage pollution, evaluate impacts, study recycling/treatment and disposal alternatives, and review regulatory compliance.

International experiences support the creation of a network to develop EBP. For instance, in 2003 the US Environmental Protection Agency (EPA) in partnership with the Shipbuilders Council of America (SCA) created a pilot group of shipyards to generate Environmental Management strategies, providing a customized implementation guide, training workshops, a forum for discussion, and technical support. As a result, a lot of the US shipyards have adopted the implementation guide, accomplishing significant improvements in their operations.

In Colombia, the Science and Technology Corporation for the Development of the Naval, Maritime, and Riverine Industries – COTECMAR is the leading company of the shipyard industry and hasinitiatedseveral strategies with the support of the national government and the academy to strengthen the sector with regards to aspects like technological capabilities, local supply chain, trade regulations, and environmental management, as shown in Fig. 1. COTECMAR also coordinates the International Ship Design and Naval Engineering Congress (ISDNEC) and the *Ship Science & Technology journal*, the most representative journal in Latin America regarding Naval Engineering.

Fig. 1. Sector initiatives where COTECMAR participates



The aim of this work is to present the experience of the Colombian shipyard industry in developing an EBP guide with a pilot group of local companies.

Inter-firm cooperation strategies

The conventional business model of organizations with an individualist focus has emerged to a new concept that associates openness and cooperation, where terms like cooperation networks, strategic alliances, and clusters are a new language for organizations to enhance development and sustainability (*Christopher, 2009*).

Based on this, special interest has emerged in literature and policy systems to createmechanisms that enable the growth of industrial sectors and their integration with government and academy, seeking to increase technological capabilities and competitiveness (*Dewick and Miozzo, 2004; Felzensztein, et al., 2010*), allowing innovation to occur within the company's products and processes (*Brioschi et al., 2002; Nieto and Santamaria, 2007; cited by Zeng, et al., 2010*).

Several authors argue that one of the principal factors that influence learning and innovation capabilities among companies is geographic proximity (*Porter, 1998; Freel, 2003; Felzensztein, et al., 2010*), which is why some countries have developed regional strategies around technologies or industrial sectors.

In Colombia, the government has led diverse cluster initiatives during the last decade, like regional competitiveness plans and the Productive Transformation program, both created to develop world-class industrial sectors and generate employment.

Brief history of the colombian shipyard industry

The first shipyard in Colombia was founded in Barranquilla in 1929, named Industrial Union and Shipyards (UNIAL, for its name in Spanish). Then, in 1942, the first Naval Shipyard was created,fully-equipped to repair Colombian Navy ships and privately owned ships.

To boostthe Naval construction in the Caribbean, the ShipyardCompany and Naval Services (EDANSCO, for its name in Spanish) was foundedin 1956. This firm created a decade later in association with the Institute of Industrial Promotionthe Colombian Company of Shipyards (CONASTIL, for its name in Spanish). CONASTIL penetrated successfully onto the market, building a fully-equipped facility in Cartagena's industrial sector (Mamonal) with 3600 tons of lifting capacityand operating until 1994, when the company was closed because of administrative problems. This fact introduces the Colombian shipyard industry into a crisis that affected the national maritime power and other related industries.

Amid this situation in the industry, the Colombian Navy decided to reactivate the CONASTIL facilities, creating the Science and Technology Corporation for the Development of the Naval, Maritime, and Riverine Industries (COTECMAR), a milestone that initiated a new period of growth for the industry.

Nowadays, the shipyard industry is consolidated in the Colombian Caribbean region, witharound 20 shipyards and naval workshops. One of the main achievements is that the industrial activity has been established in Bolivar's regional competitiveness plan (2008) as a potential world-class sector, which brings national recognition an enables the possibility to develop policies regarding trade regulation, incentives, environmental management, etc.

Adoption of environmental guides in Colombia

Environmental guides are instruments that seek to include environmental factorsin the process of planning and developing operations in industrial sectors, acting as a technical referenceinprojects or other activities regarding the nation's main industries.

These guides were created by the Colombian Ministry for the Environment and were adopted through Resolution No. 1023 of July 28, 2005, as an instrument to undergo self-management and self-regulation, and also as a conceptual and methodological reference. There are 45 guides operating, impacting five industrial sectors: Oil, Energy, Agriculture, Manufacture, and Transport.

On this Resolution, the paragraph in the third articleestablished that the Ministry can adopt new guides, offering an opportunity for other sectors to properly manage the environmental impact of their processes.

Environmental management in the colombian shipyard industry: the sectorial process

The environmental guide for Colombian shipyards is part of the sectoral initiatives coordinated by COTECMAR, promoting the development of the industry on scientific, technological, and productive aspects. It addresses one of the main problems that most enterprises encounter: environmental impact of industrial processes. Ignoring this can affect the company's relationships with the stakeholders and its expansion plans, but managing it properly can increase productivity and support social responsibility programs.

Several players have participated in this collaborative process, including national and international companies, the academy,and associations, enabling the elaboration of a preliminary document to be presented to the Ministry for the Environment and its eventual adoption by the companies of the industrial sector. The process is shown in Fig. 2.

Baseline

The process started with the construction of a Baseline of the environmental activity of the national shipbuilding sector. A pilot group was selected for this phase, including four of the most representative shipyards in Cartagena (2), Barranquilla (1), and Urabá (1), along with a world-class shipyard located in Chile . These companies were selected by taking into account their production processes, products and services portfolio, and the environment where they operate. Every facility was visited to analyze processes and their impact upon the environment, as well as to learn of the EBT actually being developed by each company.

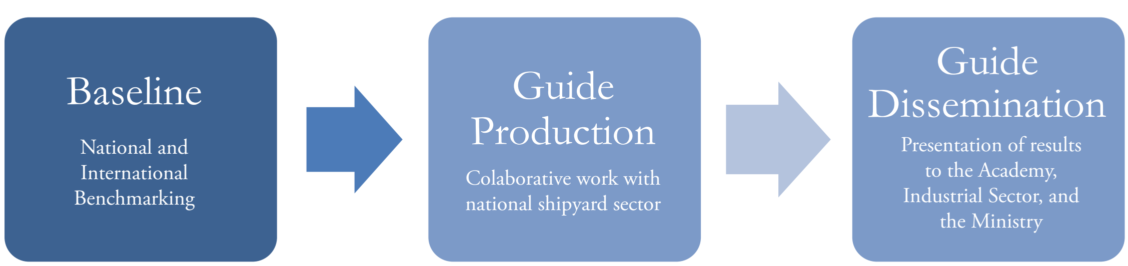
Guide Production

With the baseline defined, the production process was performed via three workshops: Law and Regulations review, identification of Environmental Impacts, and Environmental Management Plan. The discussion was developed by considering shipyard construction and operations. The methodology andmain results obtainedfrom each workshop are presented below.

Workshop 1: Law and Regulations review

Shipyard activities in Colombia are not obligated to have Environmental Licenses, but they need to secure certain permissions and authorizations from the environmental authorities (forest utilization, water concessions, liquids dumping, dangerous and/or solid residues, etc.). In this process, all the procedures and templates required were identified. A special chapter was developed in the Guide reviewing this aspect.

Fig. 2. Environmental guide production process



Workshop 2: Environmental Impacts identification

The environment provides human beings important resources for development, like raw materials and energy. A small amount of these resources are renewable, which is why their proper management is required.

Every activity generates an impact on the environment. The level of these impacts depends on the vulnerabilityof the elements of the ecosystem where the industrial activity is being undertaken. The guide contains all the impacts identified and the plans to prevent, control, or mitigate them, as shown in Fig. 4.

Fig. 3. Workshop on Identification of Environmental Impacts

Identification of impacts was performed by using a cause-effect matrix that contained the activities and the possible impacts according to previously definedprocesses and aspects. Every environmental

Fig. 4. Environmental impacts identified

Environmental Element	Environmental Impact	Scope
Geo-forms	Shore Erosion	Changes or instability presented on ocean and river shores
Soils	Soil win/loss	Volume of material to be added or extracted
	Soil Contamination	Incorporation of unknown matter to soil that produces physical, chemical, and biological instability
Atmosphere	Air Contamination	Increase/Decrease of composite concentrations (e.g. CO, SOx, NOx) and particulate material in the atmosphere
	Noise Level Alteration	Increase/Decrease of decibels according to standards
Water	Water Contamination	Incorporation of unknown matter to water
	Riverbed Alteration	Changes on riverbed morphology caused by dredging
Flora	Aquatic Flora Alteration	Damage caused to species of aquatic, marine, and riverine flora
	Terrestrial Flora Alteration	Damage caused toterrestrial flora
Fauna	Aquatic Fauna Alteration	Damage to aquatic fauna as a consequence of shipyard activities
	Terrestrial Fauna Alteration	Damage to aquatic fauna as a consequence of shipyard activities
Perceptual	Scenic Value	Alteration of shapes and elements that allows aesthetic enjoyment
Natural Resources	Resource demand	Refers to utilization of natural resources
Socio-economic	Social Conflicts	Conflicts that could emerge with communities or institutions
	Worker Health Alteration	Health alteration to workers as a consequence of their exposure to risks while they perform their job functions

delegate of the pilot group's companies filled out the matrix according to the specific ecosystem of their facilities.

Workshop 3: Environmental Management Plan

Based on the results of Workshop # 2, the following activities were completed:

a. Definition of Environmental Management Programs, including measures to be implemented to mitigate, control, prevent, and/or compensate environmental impact.
b. Monitoring and controlling plan, with activities to audit the goals established in the management plans defined.
c. Identification of efficiency indicators to accomplish the activities defined on the management plans.
d. Elaboration of a contingency plan, based on the risk analysis and the actions aimedat guaranteeingproper management of technical, human, and economic resources to address potential emergency situations.

The results obtained on the three workshops with the pilot group allowed elaborating a preliminary document to work with other players from the national economy.

Guide Dissemination

The document elaborated in the production stage was presented in two scenarios:

- The Academy, represented by the Colombian Network of Environmental Education (RCFA, for its name in Spanish). This network has the goal of creating cooperation scenarios to discuss topics regarding sustainable development. It also organizes the Environmental Science & Technology congress, and the guide was included as one of the main topics for discussionin the Integral Coastal Management Chapter.
- The industrial sector, represented by the Shipyard Committee of the National Association of Industrialists (ANDI, for its name in Spanish).

The document is currently being adapted with the feedback from the Academy and the Industrial Sector. Once this stage is completed, the document will be presented to the Colombian Ministry for the Environment to be incorporated as a formal guide representing shipyard operations.

Conclusions

The Colombian shipyard sector is an industry that has been growing for the last decade and has the potential of becoming consolidated as a world-class industry in the long term. As the sector increases its industrial and technological capabilities, it is important to develop EBP to guarantee sustainability.

The existing mechanisms to develop EBP in Colombia are the environmental guides. There are 45 guides currently operating, and there is a possibility to develop new ones if the Colombian Ministry for the Environment considers it appropriate.

This project is part of the sectorial strategies led by COTECMAR to increase the competitiveness of the shipyard sector and its national recognition. The results obtained can be used to optimize operations and construction of national and international shipyards and, also, as a reference on network collaborative work.

References

BRIOSCHI, F., BRIOSCHI, M.S., CAINELLI, G. (2002). From the industrial district to the district group: an insight into the evolution of local capitalism in Italy. Regional Studies 36 (9), 1037–1052.

CHRISTOHPER, M., GAUDENZI, B. (2009). Exploiting knowledge across networks through reputation management. Industrial Marketing Management 38 191–197.

DEWICK, P., MIOZZO, M. (2004). Networks and innovation: sustainable technologies in Scottish social housing. R & D Management 34 (4), 323–333.

FELZENSZTEIN, C., GIMMON, E., CARTER, S. (2010). Geographical Co-Location, Social Networks and Inter-firm Marketing Co-operation: the Case of the Salmon Industry. Long-Range Planning 43 675 – 690.

FREEL, M. (2003). Sectoral patterns of small firm innovation, networking and proximity Mark S. Freel. Research Policy 32 (2003) 751–770.

NIETO, M.J.,SANTAMARÍA, L. (2007). The importance of diverse collaborative networks for the novelty of product innovation. Technovation27(6–7). 367–377.

PORTER, M., (1998). On Competition. Harvard Business School Press, Cambridge, MA. Zeng, S., Xie, X., Tamc, C. (2010). Relationship between cooperation networks and innovation performance of SMEs S.X. Zeng a, X.M. Xie b, C.M. Tamc. Technovation 30 181–194.

Environmental Impacts of Shipbuilding and Repair Operations (2008). Pacific Northwest Pollution Prevention Resource Center (PPRC)

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Acknowledgments may be made to persons or institutions considered to have made important contributions and not mentioned in any other part of the article.

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