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MARITIME CASUALTIES ANALYSIS AS A TOOL TO IMPROVE RESEARCH ABOUT HUMAN FACTORS ON MARITIME ENVIRONMENT.

R. de la Campa Portela[1]

ABSTRACT

It is commonly accepted that approximately 80 per cent of maritime accidents are due to human error. However investigation in human factors, main cause of such accidents, is beginning nowadays, and the methodologies to carry out such an investigation are being developed by several institutions. These methodologies, adopted from the investigation on risk analysis are frequently based on the estimation of risk levels, whose values, in the case of human factor investigation are not always clear.

This article tries to develop a methodology that helps us to identify the human factors existing on a maritime accident with the aim of making them processable on a statistical basis, in any case the aim of the study is not to exchange the existing and well –established systems of accidents analysis, but to put more stress on the human element, that is included in the existing analytical systems.

Keywords: risk assessment, maritime accidents, human factors.

INTRODUCTION

Following Garrick (1999) there are several basic aspects of maritime activity that make it unique: ships are confined and isolated systems, self-sufficient on energy supply, they have a limited manpower and resources, and they have a limited

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response capacity to face emergencies. These particular characteristics made maritime trade a risky activity, where a fault in navigation or in usual port operations can give rise to injuries or lost of life, to damage of property and some times irreparable damage to maritime environment. Environmental and operational risks that can give rise to costly demands and complaints, are nowadays, in opinion of Palmgren (1999), a significant matter to owners, and the evaluation of these and other risks is an essential requirement to maritime trade safety.

Although risk, inherent to maritime industry, can not be completely removed (UK P&I Club, 1999; Peek and Rawson, 2000), it can be reduced to acceptable levels through the use of risk management principles. However before putting in practice a risk management plan, the owner must identify, evaluate and prioritize the main existing risks.

On the other hand, several researches (UK P&I Club, 1999, US Department of Transportation, 1999) identify human error as cause of 60 and 80 per cent of maritime accidents, giving us an idea of the importance on maritime safety of quality living conditions on board –related to ship condition and maintenance– and quality of crews – related to crew competence and qualification.

Since human factors –trigger of human errors– are the main source of risk in maritime activities, it seems interesting to develop methodologies that allow evaluating quantitatively and qualitatively the real incidence of several human factors over maritime accidents happening with the aim of taking human factors into account in properly developing risk management plans.

So present article shows a methodology that takes easy to determine human factors risk levels through statistical analysis of maritime accidents.

HUMAN FACTORS AS MAIN CAUSE OF MARITIME ACCIDENTS

Maritime activity is, without any doubt, a risky activity, and maritime disasters, that had happened through the years and which will happen in an inevitable way, are due to the complex environment of ship operation. Although maritime transport has a relatively low death and injury rate –180 estimated fatalities in 1995, against 45 000 fatalities in road accidents happened the same year in the European Union–, the consequences of an accident happening are sometimes far reaching. The repercussions of oil pollution or large loss of life in a passenger carrying vessel, can reverberate for many years and take their toll on businesses, small economies and even governments (European Transport Safety Council, 2001a).

On the other hand, and such it is indicated by Caridis (1999:11) "despite the significant advances that have been achieved in recent years in the field of marine technology, the number of maritime accidents that occur on a world –wide basis has not reduced significantly". This is due to, without any doubt, and as it has been shown in several studies, the high proportion of maritime accidents related to human factors– up to 80%.

So, even nowadays, when navigation instruments use new and advanced technologies, human error is generally accepted to be the main cause of such casualties. In relation to this, it is pointed out (Moreton, 1997) the wrong tendency to think that these new and improved technologies and rules can counteract the human limits increasing safety at sea, even when such technologies and rules are frequently developed in an isolated way, instead of being developed in an integrated way as a component of the navigation system.

In that sense, and following the *Report on suggestion for the integration of human factors in safety and environmental analysis* (Thematic Network for Safety Assessment of Waterborne Transport, 2003), there is a broad agreement that the key means of lessen the human element contribution to accidents will be via safety management, including inspection and training.

ACCIDENT PREVENTION: RISK ASSESMENT AND INVESTIGATION.

Generally it can be said that maritime accidents prevention has nowadays two sides that use, to a great extent, as work base data, those from maritime accidents and incidents reports:

— Proactive work, commonly named as risk assessment, whereby the risks are assessed beforehand and measures are introduced to reduce them happening; and

— Reactive work, where accidents are investigated and analysed to find the causes to prevent a reoccurrence. The European Transport Safety Council indicates in the "Transport accident and incident investigation in the European Union" (European Transport Safety Council, 2001a) that many states recognise that this approach makes a major contribution to improve safety.

Risk Assessment

The application of risk assessment techniques, as pointed by Fowler and Sorgard (2000) has been identified as an important tool for risk management by the International Maritime Organization.

There are, in fact, a considerable number of methodologies and techniques aimed to the identification and analysis of human error as to its prevention and decrease of its occurrence (European Commission, 1999). These can be emphasized amongst others:

— Formal safety assessment developed by International Maritime Organization.

— The method of performance influencing factors (PIF) applied by SINTEF group.

— TRIPOD- method: it was developed by SHELL.

— THERP (Technique for human error rate prediction): developed at Sandia National Laboratories.

In any case, risk assessment consists of:

1. Identifying the hazard in the system
2. Evaluating the frequency of each type of accident
3. Estimating accident consequences
4. Calculating various measures of risk, such as death or injuries in the system per year, individual risks or frequency of accidents of a particular kind.

The results obtained from risk assessment can be used as basis to the implementation of new safety measures or to the change of those existing: "assessment of risk contributes to effective strategies for casualty reduction, by helping to show where scope for applying different safety measures lies" (European Transport Safety Council, 2003:7).

Accident Analysis

On the other hand we have the reactive work consisting, as we pointed formerly, on the investigation over accidents with the aim of revealing its original causes and based on it, to establish prevention measures to face similar situations: "effective accident and incident investigation makes a positive, and long lasting, contribution to the improvement of transport safety" (European Transport Safety Council, 2001a:1).

In the particular case of human factor investigation, Marine Accident Investigators International Forum (MAIIF) states, in its *Accident Investigation Guide*, the next objectives when an analysis over maritime accidents is being done:

— discovering how limitation in human performance could have caused or contributed to the occurrence;
— identifying safety hazards conductive to human error or arising out of limitations in human performance; and
— making recommendations designed to eliminate or reduce the consequences of faulty actions or decisions made by any individual or groups involved in the occurrence.

At the same time, it is broadly recognised that accidents rarely are due to an only event, but more often they are caused by a combination of individual, technological and organizational factors. In maritime settings it can be said that human element is the most important factor, acting in near 80% of accidents. Therefore, accident analysis consists basically in determining the causes that started it and to establish, in a later stage, the relationship between them. Following Hollnagel (2005) accident starting causes can be interrelated in several ways, giving rise to three kinds of accident models:

— Sequential accident models;
— Epidemiological accident models; and
— Systematic accident models.

Such factors can be, at the same time, classified as carrier or latent – the first ones influence directly over the performance and the probability of making errors, and the second ones are errors whose effects are only clear some time after they are made (Gil de Egea et al., 2003) –and as observable or inferred factors– the first ones are directly referred on accident reports, and the second ones must be deduced from a depth study of the accident with the aid of expert investigators (Jacinto and Aspinwall, 2003).

In any case these factors must be perfectly identified and the relationship between them must be established in the most possible accurate way. With this purpose, Marine Accident Investigators Forum points in its *Accident Investigation Guide*, four kinds of analytical techniques to determine the relationship amongst human factors as cause of accidents in maritime settings:

— Events and causal factor charting analysis
— Barrier analysis;
— Change analysis; and
— Root cause analysis.

Lastly it is necessary to point out that the selection of accidents to carry out the investigation may have significant impact on the results, then it is useful to make a list of exclusive criteria to determine which accidents are suitable to analyse. The *Report on suggestion for the integration of human factors in safety and environmental analysis* (Thematic Network for Safety Assessment of Waterborne Transport) establishes the next criteria list to be used on an accident investigation over human factors:

— Reports must contain a high variety of human factors which can be clearly identified
— Reports should be related to typical and not extra-ordinary accidents;
— In relation to size and kind of ship it is recommended to use accidents related to ships of 500 GT and over, which are involved in international trade and are operated under IMO regulations.

Accident and casualty databases containing highly reliable data are, therefore, essential tools to do that kind of investigations. Unfortunately, the maritime setting is characterized for having a shortage in this kind of statistical data appropriately compiled and processed. Maritime accident and incident databases are scarce and hardly accessible. Also, not all countries have a systematic method to gather information related to human factors, which makes difficult this kind of investigation (Caridis, 1999; European Transport Safety Council, 2001b; European Transport Safety Council, 2003; Harrald et al., 1998).

USEFULNESS OF MARITIME ACCIDENT ANALYSIS FOR INVESTIGATION ON HUMAN FACTORS

It is clear that total safety over ships operation can not be achieved, but it is possible to obtain a high degree on it. Research on the influence of human factors over maritime accidents is, also, very difficult. On the one hand we find that an accident involves the interaction of individuals, equipment and environment, as well as unforeseen factors (Caridis, 1999), and on the other hand, human factors comprise operative human errors –derived from personnel own qualifications, or from their physical, mental and personal conditions- and situational errors– derived form work environment design, management problems, or human-machine interface, amongst others (Gil de Egea et al., 2003).

To carry out these investigations with success, it seems necessary to face up to the next points:

1. Developing a common methodology for human error classification, which, at the same time, as pointed out by Caridis (1999) can be adopted at an international level and which can become an accepted rule. Only by this way useful and significant comparisons could be done between accidents happened in several countries.

2. It seems essential to develop research methods which allow to define maritime accidents causes with the aim of establishing, at a later stage and over these results, the more appropriate defences to avoid the recurrence of such accidents, as to design processes capable of calculating the probability of a human error to happen on a determined environment (Gil de Egea et al., 2003). These latter processes, that permit to predict with some accuracy human reliability are, for us, of increasing interest, because it is clear that it is an advance to be able to calculate the probability of an human error to happen in a specific situation.

3. Finally it is necessary to develop a common taxonomy for the storage of information in relation to accidents at sea. A high quality research is not possible without reliable, up to date and well-classified data. However maritime trade, as we have seen before, has a strong shortage in this sense, because current accident causation taxonomies and databases are untested with regard to reliability and adequacy.

With regard to investigation about human factors, several authors (Moreton, 1997; Morrison, 1997; Sröeder and Zade, 2002; Ordiz y Maza, 2002) put forward the analysis of maritime accidents as a way to understand why people make mistakes. On maritime environment such an investigation is centred in studying seamen perceptual, mental and physical capabilities, so as physical environment and working organization. The results of such investigations can be to the advantage of improving both seamen working conditions and the requirements, means and methodologies of training, having into account that ship safety starts on crew, and that a correct training is a vital element of her safe operation.

On the other hand, being risk an inherent factor of maritime activity that can not be totally removed, and being error part of human experience, it is expected that elements such as good management policies, effective training and having suitable qualifications and experience, can reduce the occurrence of human errors.

Unfortunately, the lack of objective data to evaluate the risk levels, which is a feature of maritime activity, that has no global detailed statistical data offered by International Maritime Organization (IMO) (Parker, 1999), is one of the biggest impediments for the progress of international maritime industry.

METHODOLOGICAL PROPOSAL TO AID IN HUMAN FACTOR INVESTIGATION

The investigation into an only maritime accident reveals its original causes and the relationship between them, which are specific for this particular accident. Such an investigation allows to take corrective actions with the aim of preventing accidents in similar circumstances. However it seems unlikely that the interaction between causes, or the chain of causes that originated a particular maritime accident would be repeated exactly the same way or highly similar in another accident.

However, if we take one of the causes in an isolated way and we investigate how many times such a cause appears in several maritime accidents, we would establish the probability of occurrence of such a cause in maritime accidents, and we could determine the risk that such a factor involves to maritime trade.

On the research about human error, these factors that cause the accident, commonly named as human factors, are, at least, more imprecise than the errors due to materials or equipment failure, therefore they are difficult to determine and to quantify. For this reason, a previous investigation about the presence of these factors, the different kinds of them, their root or previous cause or their occurrence frequency, seem to be interesting with the aim of establishing a clear and quantifiable object of study, capable of being investigated using statistical methodologies. In this way we could determine the risk level that the occurrence of each factor in an isolated way adds to the outbreak of accidents on the maritime environment.

A previous investigation of this kind, that combines risk assessment and maritime accidents analysis, was developed at the School of Nautical Studies of University of A Coruña, with the aim of establishing to what extent the communication problems due to linguistic differences, can be, nowadays, direct or indirect cause of maritime accidents (de la Campa, 2003).

The aim of this article is not to present the results obtained in such an investigation on a strict sense, but to show the process carried on, with the object that this process could be used as a tool to carry out other investigations aimed to study the influence of several parameters related to human factors on maritime accidents.

So, the investigation carried out at University of A Coruña consisted of the next steps:

1. Step 1: Hazard identification and quantification: through maritime accident analysis it is determined the probability of appearance of the studied human factor, and the consequences derived from its appearance. This step consists of:

a. Choice of investigation field.

b. Data collection.

c. Data processing and analysis.

d. Conclusions establishment.

2. Step 2: Risk level determination: from probability and consequence values established on step 1, and with the help of a risk matrix we could determine the risk level of the studied human factor.

Hazard Identification

Choice of investigation field

The parameters that must be established in relation to the choice of investigation field could be the next:

1. Working subject: the working point will be the human factor item which is interesting to investigate. In our case, for example, we have chosen to study the communication problems due to linguistic differences.

2. Period of study: another important point is to decide the period we want to investigate on, so the study can be focused on a certain period- for example after or before the coming into force of some rules or regulations related to the human factor of the study- or to look for current data studying accidents happened recently. In our study we have decided to investigate accidents happened between 1994 and 2001.

3. Maritime community of study: the investigation can be focused on a specific country or group of countries with the aim of concentrating on a specific maritime community, or to give it a global nature. The latter option was elected in the example investigation.

Data collection

According to the selected period and maritime community, we can use several information sources that provide us with the data about maritime accidents. In general, every country carry out investigations about the maritime accidents happened within its territorial waters, and about accidents in which any ship authorized to hoist its flag has been involved. The final reports are published on several ways by the country authorities. In our particular case we have made use of the accident reports published on the Internet by several authorities such as “The Australian Transport Safety Bureau”, “Transport Safety Board of Canada”, “The Maritime Safety Authority of New Zealand”, “The Marine Accident Investigation Branch of United Kingdom” or “The National Transportation Safety Board of U.S.A.”.

Data processing and analysis

Once reports have been compiled, we proceed to the report selection, first, and to the data analysis, later.

1. Report selection: amongst the obtained reports we must reject those that are not interesting for our investigation, that is to say, those in which the inexistence of the studied factor is proved, or those in which it is proved that the studied factor has not been relevant for causing, developing or ending the notified accident. To

undertake this task it is very beneficial that these reports are in computer support, with the aim of making easier the selection of reports by means of searching for key words directly or indirectly related to the studied factor. So, for example, in our case, the search has been done on PDF format files, using key words such as “English”, “seaspeak”, “communication”, “vocabulary”, and so on.

2. Data analysis: once obtained the whole of reports to work on, we must establish a series of “cause parameters”. These “cause parameters” will be the several ways how the studied factor appears. Then, for example, to the factor “communication problems related to linguistic differences”, we have established the “cause parameter” that are shown in Figure 1: “External communication problems”, “Internal communication problems”, “Written communication problems”, “Misuse of standard vocabularies”, “miscommunication between master and pilot”, “bridge team working fault” and “misuse of VHF equipment”. All these factors can be classified as direct factors or as indirect factors, and both of them can cause the studied factor: communication problems.

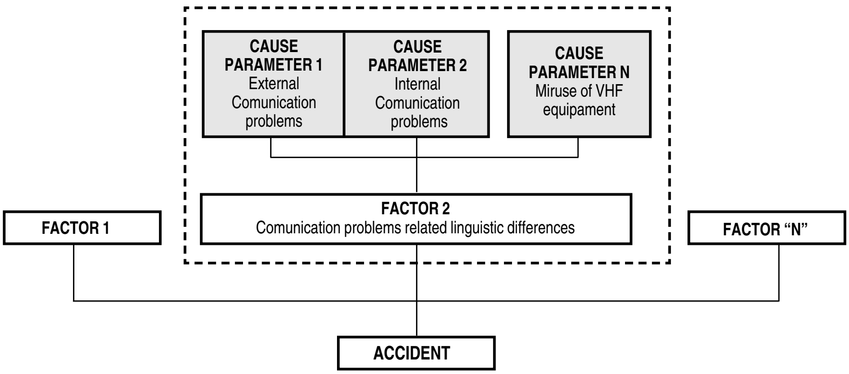

Figure 1: Cause Parameters

On the other hand, a series of “result parameters” must be established. These “result parameters” refer to the kind of accident finally happened and the seriousness of personal injuries and/or material damage suffered. Personal injuries, total loss of ship, grounding, beaching or collision are some examples of result- parameter. The Figure 2 shows the most common cause parameter found in our example investigation.

Conclusions establishment

The next step will be to compare the whole of maritime accidents in relation to “result parameters” and “cause parameters”, in such a way that the relationship between them can be established.

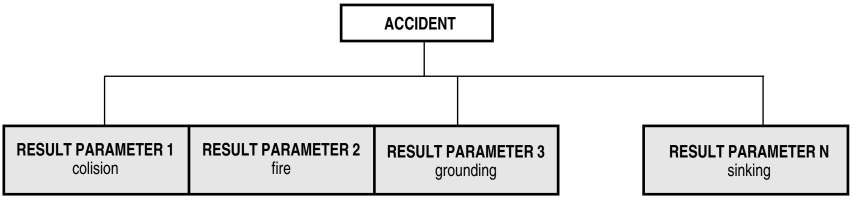

Figure 2: Result Parameters

The relationship between parameters obtained in that way, will give us the occurrence frequency of the studied factor on maritime accidents that took place on a specific period and for a specific maritime community. The occurrence frequency to each cause parameter and the most common consequences derived from such cause parameters could be established too. In the example research the most common cause parameter is "external communication problems", and the most common result parameter is "collision", as shown in Figure 3.

Risk Level Determination.

As it is well known, risk level, which give us idea of the general importance of a specific hazard, can be comprised amongst one of three assumptions:

Intolerable risk level: the risk level is too high to be justified and that it should be reduced regardless of the costs associated with the measures needed to bring the risk down to a tolerable level.

Tolerable risk level: risk levels that are assessed to be below the intolerable limit are regarded as tolerable provided it can be demonstrated to be ALARP – as low as reasonable possible. In order to demonstrate that the risk level is ALARP, cost effectiveness assessment of available risk control options must be performed. If cost effective risk control options are available, the risk level will not be ALARP and thus not regarded as tolerable until these are implemented.

Negligible risk level: the risk level is assessed to be so low that no further risk reduction measures are required.

In our case, to determine the risk level of the studied factor we are going to use a risk matrix, whose parameters are the probability of happening of such a factor in a maritime accident and its consequences, both data derived from the analysis done in step 1. To elaborate the risk matrix, that can be seen in Figure 4, we will proceed to establish five levels of probability and five levels of consequences.

Probability levels could be in this case:

1 .— 0-10%: very low probability risk level
2. — 11- 40% : low probability risk level
3. — 41 – 60%: half probability risk level
4. — 61- 90%: high probability risk level
5. — 91 – 100%: very high probability risk level.

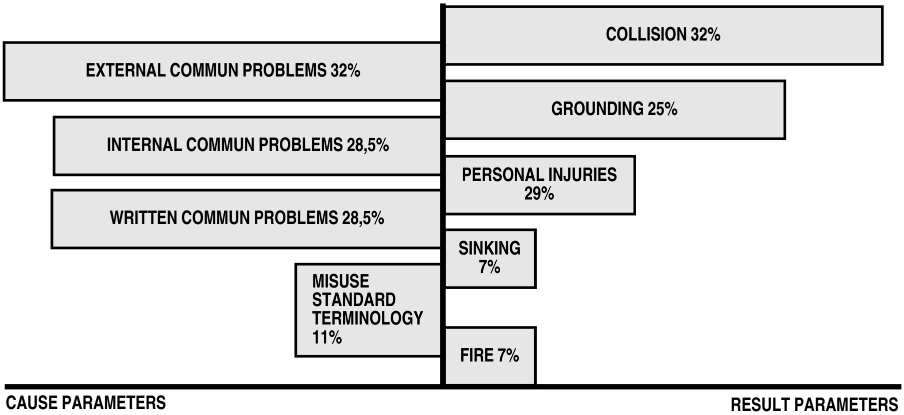

Figure 3. Consequences establishment

Consequence levels could be established as:

1. Disastrous consequences: people death, very serious damage to maritime environment, sinking or any other accident which results in the ship total lost.

2. Serious consequences: people serious injuries, maritime environment serious damage, fire, collision, grounding or any other accident which results in very serious damage to ship structure.

3. Moderate consequences: moderate injuries to people, moderate damage to maritime environment or any other accident which results in moderate damage to ship structure.

4. Minor consequences: minor injuries to people, minor damage to maritime environment, or any other accident which results in minor damage to ship structure.

5. Negligible consequences: very little damage to ship structure.

CONSEQUENCES / PROBABILITY	NEGLIGIBLE	MINOR	MODERATE	SERIOUS	DISASTROUS
0 - 10%	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	TOLERABLE	TOLERABLE
11 - 40%	NEGLIGIBLE	NEGLIGIBLE	TOLERABLE	TOLERABLE	INTOLERABLE
41 - 60%	NEGLIGIBLE	TOLERABLE	TOLERABLE	TOLERABLE	INTOLERABLE
61 - 90%	TOLERABLE	TOLERABLE	TOLERABLE	TOLERABLE	INTOLERABLE
91 - 100%	TOLERABLE	INTOLERABLE	INTOLERABLE	INTOLERABLE	INTOLERABLE

Figure 4. Risk matrix

In this way, to know the risk level of the studied factor we only need to enter in the risk matrix with probability and consequence data previously calculated, obtaining the searched risk level directly from the matrix.

CONSEQUENCES / PROBABILITY	NEGLIGIBLE	MINOR	MODERATE	SERIOUS	DISASTROUS
0 - 10%	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	TOLERABLE	TOLERABLE
11 - 40%	NEGLIGIBLE	NEGLIGIBLE	TOLERABLE	TOLERABLE	INTOLERABLE
41 - 60%	NEGLIGIBLE	TOLERABLE	TOLERABLE	TOLERABLE	INTOLERABLE
61 - 90%	TOLERABLE	TOLERABLE	TOLERABLE	TOLERABLE	INTOLERABLE
91 - 100%	TOLERABLE	INTOLERABLE	INTOLERABLE	INTOLERABLE	INTOLERABLE

Figure 5. Risk level determination

So, following our example, if we take the probability level of communication problems in maritime accidents, calculated on step 1 as 20%, and we establish the consequences of such accidents between moderate and serious, we will obtain a tolerable risk level, as it is shown in Figure 5.

CONCLUSIONS

The practical application of this kind of analysis seems clear: obtaining the cause parameters, both direct and indirect parameters, from the studied factor, we can better understand the root of the presence of such a factor, and we can take punctual, specific and direct corrective actions to try to minimize the accident risk.

In spite of it is highly simple, the main weakness of this method lies in the lack or shortage of data related to accidents and incidents on maritime domains.

The investigation on maritime accidents is, nowadays, a very important tool to identify the problems related to human factor, that, studied with attention can be one mainstay to accident prevention and to the improvement of maritime safety.

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PROPUESTA METODOLÓGICA PARA LA AYUDA EN LA INVESTIGACIÓN DEL FACTOR HUMANO EN LA NAVEGACIÓN

Resumen

De forma general es aceptado que aproximadamente el 80 por cien de los accidentes marítimos son debidos al error humano. Sin embargo, la investigación en factores humanos en el ámbito marítimo, causa principal de dichos accidentes, está comenzado en nuestros días, y las metodologías apropiadas para llevar a cabo dicha investigación están siendo desarrolladas por diversas instituciones. Estas metodologías, adapatadas de la investigación en análisis de riesgos están frecuentemente basadas en la estimación de los niveles de riesgo, cuyos valores, en el caso de la investigación sobre factores humanos, no están siempre claros.

Este artículo trata de desarrollar una metodología que nos ayude a identificar los factores humanos existentes en un accidentes marítimo con la intención de hacerlos procesables desde un punto de vista estadístico. En cualquier caso este estudio no pretende cambiar los sistemas de análisis de accidentes marítimos bien conocidos y establecidos, sino poner mayor énfasis en el elemento humano ya contemplado en los sistemas analíticos existentes.

DESARROLLO METODOLÓGICO

La investigación sobre un único accidente marítimo revela sus causas originales y la relación entre estas causas, que son además específicas para ese accidente particular. Tal investigación permite tomar acciones correctivas con el fin de prevenir accidentes en circunstancias similares. Sin embargo parece improbable que la interacción entre esas causas, o la cadena de causas que originaron un accidente concreto, puedan repetirse exactamente de la misma forma en otro accidente.

Por otro lado, si tomamos una de las causas de forma aislada e investigamos con qué frecuencia dicha causa aparece en diversos accidentes marítimos, podríamos establecer la probabilidad de aparición de tal causa en los accidentes marítimos, y podríamos determinar el riesgo que dicho factor supone en el comercio marítimo.

En la investigación sobre el error humano los factores que causan los accidentes, denominados comúnmente factores humanos, son, al menos, más imprecisos que los errores debidos a fallos en el material o el equipo, por lo que son más difíciles de determinar y cuantificar. Por este motivo, una investigación previa sobre la presencia de estos factores, sus diferentes tipos, su causa raíz o previa o su frecuencia de ocurrencia, parece interesante con el fin de establecer un objeto de estudio claro y cuantificable, susceptible de ser investigado usando metodologías estadísticas. De esta forma podríamos determinar el nivel de riesgo que la ocurrencia de cada factor de forma aislada supone en la iniciación de los accidentes en el ámbito marítimo.

Una investigación previa de este tipo, que combina la gestión de riesgos y el análisis de accidentes marítimos, ha sido desarrollada desde la Escuela Técnica Superior de Náutica y Máquinas de la Universidad de A Coruña, con objeto de establecer hasta qué punto los problemas de comunicación oral debidos a la falta o mal uso de una lengua común, pueden ser , hoy en día, causa directa o indirecta de accidentes marítimos.

El objetivo de este artículo no es presentar los resultados obtenidos en dicha investigación de forma estricta, sino presentar el proceso llevado a cabo con objeto de que dicho proceso pueda ser usado como herramienta para realizar investigaciones similares encaminadas al estudio de la influencia del error humano en los accidentes marítimos.

Así pues, la investigación llevada a cabo desde la Universidad de A Coruña comprende los siguientes pasos:

Identificación y cuantificación de peligros: a través del análisis de accidentes marítimos se determinó la probabilidad de aparición del factor estudiado y las consecuencias derivadas de dicha aparición. Este paso consistió particularmente en: elección del campo de investigación, recogida de datos, análisis y procesamiento de datos y establecimiento de conclusiones.

Determinación del nivel de riesgo: a partir de los datos de probabilidad y consecuencias establecidos en el paso previo, y con la ayuda de una matriz de riesgos se determinó el nivel de riesgo del factor humano objeto de estudio.

CONCLUSIONES

La aplicación práctica de este tipo de análisis parece clara: obteniendo los parámetros causa, tanto directos como indirectos, del factor estudiado podemos comprender mejor la raíz de la presencia de dicho factor en los accidentes marítimos, por lo que podremos desarrollar acciones correctivas directas, específicas y puntuales con el fin de minimizar el riesgo de accidentes.

A pesar de ser un método muy sencillo, su principal debilidad radica en la escasez de datos relacionados con los accidentes e incidentes en el ámbito marítimo.

La investigación en accidentes marítimos es, hoy en día, una herramienta de suma importancia que nos ayuda a identificar los problemas relacionados con el factor humano, que, estudiados con atención pueden convertirse en el soporte para la prevención de accidentes y la mejora de la seguridad marítima.

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MARITIME SAFETY CONTROL INSTRUMENTS IN THE ERA OF THE GLOBALISATION.

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ABSTRACT

For more than 30 years the International Maritime Organization (IMO) has carried out valuable work and invested a great deal of effort in implementing rules and regulations covering maritimemaritime transportation to ensure compliance with vitalin order to reach an standards of shipping safety and marine environmental protection. The SOLAS and MARPOL Conventions have been adopted in respect of ninety per cent of the international fleet. From the current situation, however, it is clear that sub-standard vessels are proliferating, and representwhat constitute a serious hazarddanger to the safety of marinemaritime navigation. The largesheer number of different nationalities , involved in maritimethe maritime transportation has motivated a cause forCoastal/Port States to try and developget into the way of protecting policies. The Paris Memorandum of Paris 1982 and other agreements are examples under consideration by thefor been considering the implementation of Port State Control (PSC). The aim of this paper, within the analysis already described, is to study the influences of these policies regarding open Register (FOC).

Keywords: Maritime Transport, Safety, Globalisation

INTRODUCTION

At the "barricades" of the new social revolution, radical protesters now rage at a common enemy: Globalisation. Some see this as the bloodiest face of the ruling world economic situation, dominated by the World Trade Organisation, the International Monetary Fund or the all-powerful World Bank. Underlying the policy

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considerations of each of these three institutions is a common denominator: world trade. And this trade, at least of physical goods, depends on a critical technological element – the ship. But ships in turn depend critically upon an appropriate operational environment with the necessary infrastructure to enable the transfer of the merchandise traded. This operational environment is the port.

Maritime transport, therefore, is an instrument of the world economic system. At the expense of being critical, we must acknowledge that in the western world, some 40% of all energy used is derived from petroleum as the primary source. Despite the investment in long-distance pipelines, experience shows that maritime transportation continues to be less harmful, in respect of risks to the natural environment, considered on a distance/load basis. Also in its favour is the existence of a substantial record of international consensus on the regulation of safety in navigation matters. Over the last 30 years, the demand for this type of transport has doubled. In the transport of crude oil and petroleum products there has been an increase of 50% over the same period (ANAVE 2000).

But the "family photo" of the world fleet in no way presents a pretty picture: there are far too many "old tubs", ships with an average age of more than 20 years, operating under an established system of flags of convenience (FOC) that constitutes a "safe haven" for substandard ships and unscrupulous owners and operators (although the relationship is not always direct). And the trend is towards such a system: while the world fleet increases, the fleets of vessels registered in the USA or the countries of the European Union suffer a continual leakage, their numbers diminishing year after year.

The creation of a specialised agency, the International maritime Organisation (IMO), for which the constituting convention was signed in 1948, represents an element of control that, through its existence, can count on more than fifty years of experience. But under the policy established by the European community, self-regulation by the sector itself should be the means by which a commitment to quality and therefore to safety should be ensured among all the parties: ship owners and operators, classification societies, brokers, shipping agents, professional associations and trades unions. The substandard ship is rightly considered the cancer of the maritime transport industry, since it is the source of a large part of its problems.

And the first of the problems arises from the impetus towards cost reduction on the part of many ship owners in detriment to the safety of their ships, which is the motive behind the registration of ships under flags of convenience (FOC).

According to the International Shipping Federation (ISF 2000), the salary of a first officer from Norway may be four times that of his Philippine counterpart. These salary differences, ultimately reflecting differences in training, are even greater in lower level jobs such as ordinary seaman or greaser.

To this should be added the changes undergone by the world of maritime transport, which constitutes a veritable transformation in the way ships are managed. Never in previous centuries have merchant seamen passed through such profound changes in such a brief period of time. The ships continue sailing between the same ports carrying the same cargoes, but those on board them have to live their lives in conditions of complete lack of confidence.

On the ships flying flags of convenience, scarcely the captain, first officer and chief engineer come from countries where levels of training are acceptable, while the rest of the crew consist of seamen drawn from such a diverse range of countries, languages and cultures that not even coexistence and mutual tolerance can be safely assumed. The average age of these ships, as at 1st January 2000, was 20 years, and Panama is the most important FOC state in the world context, with more than one hundred million in Gross Tonnage registered: this is almost 20% of all the world's merchant ships (ANAVE, 2000).

The present article therefore discusses the Port State Control (PSC) as one more means of inspection which is aimed, like the other inspection bodies, at ensuring that ships operate in conditions of safety. But the PSC is considered, from a more philosophical viewpoint, as representing the control mechanism exercised by States over maritime transport in general (regardless of a ship's Flag), faced with the reality of the globalization of trade.

EVOLUTION OF THE INSTRUMENTS OF CONTROL.

The function of the PSC consists of the inspection of foreign vessels in national ports, for the purpose of verifying that the conditions of the ship, its equipment and crew comply with the requirements demanded in International Conventions (Hoppe, 2000). The origin of the system of inspections must be sought in a problem on which the IMO has, since its inception, concentrated its efforts: assuring that all ships meet certain minimum requirements so that they do not present a danger to safe navigation, and guaranteeing that the living conditions of crews are acceptable.

These efforts of the IMO have been channelled into two different lines of action: on one hand, the preparation of International Conventions that oblige signatory Flag-issuing states to comply; and on the other, the real and effective implementation of these Conventions by the states ratifying them. If we analyse separately these two lines of action, one legislative and the other executive, we come to the conclusion that in respect of the International Conventions, the efforts of the IMO have borne fruit, but not so the work of implementation by the Flag-issuing states (Piniella, 1997).

This means that some states that on paper accept the commitment that the ships flying their flag should comply with specified conditions, in practice either do not accept this commitment or are unable to accept it. Their ships can thus avoid the provisions of these International Conventions. Clearly in this situation, competition can develop between FOC states regarding the conditions or lack of conditions attached to the registration of ships.

In some cases, this dysfunction is due to lack of political will on the part of FOC states, whereas in other cases, the problem lies more in the lack of the human and physical resources needed by these states to exercise control over their registered fleet, particularly over registered ships that do not frequent their own ports. In a brief summary of the problem, we can state that we are describing a world in which the two sides of the coin in question are the Flag-issuing states (FIS) and the PSC of the states into which the ship sails.

To seek a solution, this question was discussed in a plenary session of the IMO at the beginning of the 1990's. The outcome was the creation in 1992 of a new Sub-committee. This was to report to two main Committees, the Maritime Safety Committee (MSC) and the Marine Environment Protection Committee (MEPC), and was designated the Flag State Implementation or FSI Subcommittee.

The functions of the FSI Subcommittee are, among others, to determine what difficulties the Flag States face in implementing the International Conventions that they have ratified; to estimate the extent to which these states are complying with the obligations contracted under these Conventions; and to put forward proposals for providing assistance to those states in putting into practice these obligations as specified and contracted (Piniella, 1997).

These functions of the FSI Subcommittee are carried out through three main channels of action: 1. Preparation of Directives for the Flag States; 2. Preparation of statistics and investigation of accidents; and 3. Technical assistance

However, the creation of the FSI Subcommittee has not been a panacea. The harsh reality is that maritime accidents continue to happen, with loss of life, goods and damage to the marine environment. Although other causes intervene, these are mainly due to[1] :

a) An increase in the average age of the world's merchant fleet;
b) Insufficient maintenance of material and equipment;
c) A growing shortage of experienced crews;
d) Failure to observe international safety standards.

In the light of this situation and even before the formation of this IMO Subcommittee, the PSC authorities, the other party involved in supervising international maritime traffic, recognised the need to ensure maritime safety and the protection of the marine environment in their own ports and coastal waters. The action proposed for this was to monitor foreign ships that visit their ports, and if justified to detain or prohibit the entry of ships not complying with the provisions of the International Conventions, which ships were henceforth designated "substandard ships".

When a state, in function of registering ships to sail under its flag, has ensured that all the ships of its fleet conform to the requirements demanded in the International Conventions, the next step for it is to take measures to avoid the

[1] http://www.sudnet.com.ar/ciala/iniciala.htm

occurrence of "incidents" in its coastal waters. For this, the state must ensure that foreign ships visiting its ports comply with the same requirements as its own registered ships.

As we have already seen in its definition, this principle of action or authority is what constitutes the Port State Control. The origin of this system of control, in existence prior to the formation of the FSI, as already noted, is found in two previously developed models:

— The American model of the U.S. Coast Guard (1970).
— The European model of the Memorandum of Understanding (MoU) of París (1978).

With respect to the North American model, this does not involve a system of transfer of information between countries like the European approach, but rather, it is a unique model that arose in response to the decrease of the fleet registered under the US flag. At the present time, US-registered ships account for barely 5% of the total ships entering US ports. The U.S. Coast Guard makes control inspections of some 7,500 ships each year. Its PSC system was standardised effectively in 1994 when the Federal Government put into practice its program for the detection of substandard ships.

The responsibility and management of the PSC is carried out by means of the 45 Captaincies of the Coast Guard among which all the coastal zones of USA territory is divided. The system of selection of ships for inspection used by the US Government is very particular to that country, and is based on a priority matrix known as the Boarding Priority Matrix or BPM. Under this method, four levels of priority are established on the basis of a series of points that the ship accumulates in function of whether or not it is registered with one of a series of black-listed countries, shipowners or classification societies. In the compilation of these black-lists, statistical data of the past three years are used. The system of information is fundamental to the US approach, and this information is available on the Net and is universally accessible.

The MoU of Paris is based on the previous experience of what was known as the Memorandum of The Hague, signed in 1978 by a group of 8 European countries with the aim of reaching an agreement to adopt uniform criteria for the inspection of working conditions on board ships, according to the provisions of Convention 147 of the International Labour Organisation (ILO).

However, the agreement of The Hague had hardly come into effect when the oil tanker *Amoco Cadiz* ran aground in the English Channel. This incident and its disastrous consequences spurred these countries into reappraising their preventive policies. As a result the original agreement was remodelled and extended to cover other matters contained in other International Conventions related to maritime security and protection of the marine environment. Thus was born in 1982 the first international agreement on the unification of criteria for the inspection of foreign ships by PSC authorities, signed in principle in Paris by 14 countries and termed the Memorandum of Understanding of Paris.

The framework of the MoU of París is based on mainly geographical criteria, although an Annexe has been included specifying quality conditions for the inspection services. At that time the signatory countries were: Belgium, Canada, Croatia, Denmark, Finland, France, Germany, Greece, Holland, Ireland, Italy, Norway, Poland, Portugal, Russia, Spain, Sweden and the United Kingdom. The fundamental principles of the MoU are:

— Responsibility for the safety of ships rests with the ship owner or operator.
— The PSC authorities must inspect, in accordance with the International Conventions, at least 25% of the foreign ships entering their ports.
— Favourable treatment must not be shown towards ships of any particular flag.
— And inspection procedures must be adequately harmonized among these countries.

The information used by the MoU of París is that known by the initials SIRENAC, although currently there is a trend towards a new system of information known as EQUASIS. This new system is an initiative of the European Union which was introduced in 1997 and was set up at the Conference on Quality in Maritime Transport, during the Portuguese presidency of the European Union in 1998. The participants in EQUASIS not only comprise the European countries but the US Coast Guard and some Asian countries such as Singapore and Japan are also partners.

Does this development mean a diminishing of the traditional role of the Registering or Flag-issuing State as ultimately responsible for the safety of its ships? (Plaza, 1997). Not necessarily. These regional MoU's should be regarded as tools of prevention, aimed at the eradication of the substandard ship, as is the FSI Subcommittee. The principles of action are different but complementary to those of the FSI. Whereas the function of the FSI Subcommittee consists of providing technical assistance to the registering State so as to put into effect the requirement of the International Conventions, the PSC for its part pursues the ships not complying with the provisions of these Conventions, even ships registered by states that have not ratified these Conventions.

Promoted by the IMO, in recent years seven more agreements have been signed on PSC procedures, all of them regional in character; an eighth is still in the project stage:

a) Agreement of Viña del Mar (1992), between the Maritime Administrations of the coastal states of South America;
b) Memorandum of Tokyo (1993), between the Administrations of the coastal states of the Asiatic region of the Pacific.;
c) Memorandum of the Caribbean (1996);
d) Memorandum of the Mediterranean (1997);
e) Memorandum of the Indian Ocean (1998);
f) Memorandum of the Western and Central regions of Africa (1999);

g) Memorandum of the Black Sea region (2000);
h) Memorandum of the Persian Gulf (Projected).

The IMO continues to promote the signature of new agreements, concentrating its work on two fundamental aspects:

a) The States that carry out PSC have to be supported by efficient maritime Administrations, that can count on properly trained, experienced staff who are adequately remunerated.
b) The establishment of new agreements requires not only the collaboration among the signature states but also external support and collaboration. Each signature state depends on the others when it comes to allocating the financial resources necessary for the establishment and continuing operation of the agreement; as well as requiring technical and financial assistance, they also need access to the information and data bases maintained by third countries (Plaza, 1997).

SUBSTANDARD SHIPS AND FLAGS OF CONVENIENCE.

Background

Previously we had to place on record the legal and economic questions that stem from the irregular behaviour of the control of the fleet, to the detriment of a generalized implementation of inspections by the State of the port. Up to the 1960's, the manifest dangers from maritime transport did not cause public alarm to anything like the extent provoked by later events. These more recent years have been marked by a seemingly interminable list of ship's names like "Amoco Cádiz", "Exxon Valdez", "Aegean Sea" or "Erika".

Consequently the proliferation of flags of convenience (FOC) now represented not only the diversion of fiscal funds from the developed countries to others, which offered their flags to the shipowners of the First World as a means of obtaining foreign currency: this practice was clearly giving rise to the phenomenon of substandard ships with the characteristics that are widely acknowledged: insufficient safety equipment; poorly trained crews; ineffective control by the registering State. All this has constituted a latent danger of marine accidents on the coasts of the States on the receiving end of world maritime traffic. The evolution of the international fleet by flag of registration can be appreciated in Tables 1 and 2, which shows the generalized decrease

Table 1: Evolution of the registered fleets of the EU and the USA, in relation to that of the total world fleet.

	1975	1980	1985	1990	1995	2000
USA	14587	18464	19518	21328	13655	12026
European Union	113014	127436	93432	63116	72423	75082
World Fleet	342162	419911	416269	423627	457914	543610

Source: Authors' own, using data from the ANAVE 1999-2000 Report (data in'000 GT).

Table 2: Comparison between three Western and three FOC countries

	1975	1980	1985	1990	1995	2000
USA	14587	18464	19518	21328	13655	12026
Spain	5433	8112	6256	3807	1560	1903
France	10746	11925	8237	3832	4348	4425
Panama	13667	24191	40674	39298	64170	105248
Liberia	65820	80285	58180	54700	57648	54107
Bahamas	190	87	3907	13626	22915	29483

Source: Authors' own, using data from the ANAVE 1999-2000 Report (data in '000 GT)

of the European and North American flags in comparison with the growth of FOC. Among these FOC states should be noted the pronounced leading role of Panama, which in the year 2000 exceeded the total of 100 million gross tons for the first time, followed by Liberia and the Bahamas.

Against the negative element of this *"flagging out"*, note should be taken of an inverse process of control that has caused an authentic revolution in the Law of the Sea, with the aim of closing a loophole that should make it impossible for a ship not to comply with the minimum levels of safety, including in respect of contracting crews with minimal maritime traditions. Since the end of the 1970's, a series of International Conventions have been approved more favourable to the exercise of control by the coastal State. These began with the establishment of a ruling on minimum levels of training, with the approval of the STCW in 1978, which came into force in 1984.[2]

In respect of the Maritime Administrations of the FOC States, in addition to the problem that their registered ships very rarely put into port in their flag country (a typical example of a FOC country: a Caribbean island often of minuscule size), it happens that the actual work of controlling ships amounts to little more than whatever can be done by the consuls and by the Classification Societies. This problem of "delegation" to "recognized organizations" is another even more negative factor. For Fernández Beistegui (2000): *"the causes are mainly economic in nature, connected with the commercial interests of certain companies, although political interests are also involved in certain States that wish to depend on their own Classification Societies to help them in the development of their fledgling maritime industries"*. In any case, the instructions and regulations of minimum requirements established by the IMO in respect of "recognized organizations", of which we have spoken, to which the administration of FOC fleets are delegated, have represented a qualitative leap of improvement in the reduction of risks of maritime accidents.

[2] In any case, the generalization of the so-called white list of countries of approved training, under pressure from the shipowners, has created a crisis for the validity of the system.

[3] These sources have been utilized since other MoU's, such as that of Viña del Mar, restrict the information available on the Net thus preventing access to all the data that have been obtained for the three systems selected: the MoU's of París, Tokyo (especially AMSA –Australia-) and the system of the American USCG.

In order to analyse the level of effectiveness of the system of control exercised by the coastal states, we have consulted the following Reports:[3]

1) Annual Report MoU Paris (+Blue Book).

2) Annual Report on PSC in the Asia-Pacific Region (+PSC Report Australia).

3) Port State Control Report U.S. Coast Guard.

Based on these sources of information, we shall determine firstly certain quantitative aspects, and finally we shall carry out a qualitative study of aspects relevant to Maritime Safety.

Index of the Rigorousness of the Controls.

In Europe the proportion of inspections has evolved over the past 10 years by less than 4%, from 23.7% in 1991 to 27.6% in 1999, with all the countries members of the MoU of Paris presenting a uniform rate of inspections apart from Ireland. However, in the countries of the MoU of Tokyo such uniformity of action is not seen, and there are variations between the countries such as Australia and New Zealand which inspect 60% of foreign ships, and others such as Singapore and Malaysia where the rate does not exceed 10%; in between are countries such as

Table 3: Index of inspections by Entry in ports.Total numbers of inspections made.

Country	% Index of inspections by Entry in ports.	Total numbers of inspections made.	Country	% Index of inspections by Entry in ports.	Total numbers of inspections made.
Belgium	20,4	1383	UK	28,4	1870
Canada	27,4	707	USA	22	11540
Croatia	90	438	Australia	59,46	2753
Denmark	20,4	590	Canada/Pacific	18,34	350
Finland	31,1	448	China	21,29	1510
France	14,1	819	Fiji	45,87	100
Germany	25	1743	Hong-Kong	16,13	900
Greece	27,3	730	Indonesia	15,24	853
Ireland	7,5	100	Japan	32,75	3579
Italy	37,5	2194	Korea	19,68	1846
Holland	32,3	1825	Malasya	6,38	338
Norway	19,6	358	New Zealand	60,26	743
Poland	31,4	601	Philippines	5,55	135
Portugal	29,2	758	Russia	45,53	428
Russia	53,3	1454	Singapore	9,18	1019
Spain	29,6	1654	Thailand	2,32	83
Sweden	26,9	727	Vietnam	24,77	270

Source: Authors' own, using data from the Reports of 1999 of the MoU's of París, Tokyo and the USCG.

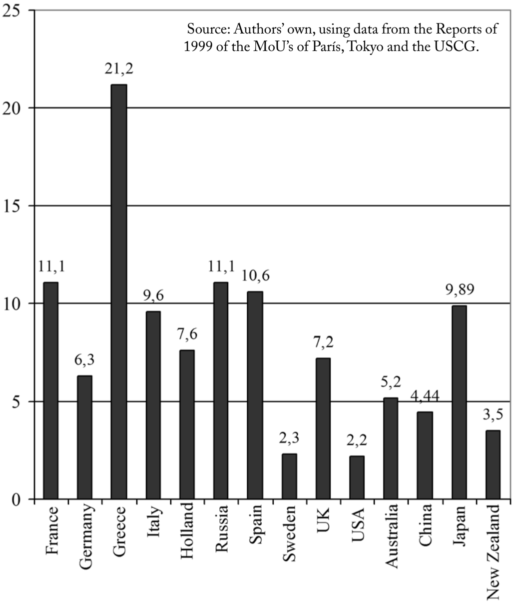


Fig.1: Index of detentions as a percentage of inspections.

China, Canada and Japan with inspection rates of 20-30%. In the case of the USA, the Coast Guard presents a rate of inspections of around 22% or more.

In Table 3 we can see a comparison of some of the countries of the world in respect of the total number of inspections made in 1999.

If the general picture is one of lack of uniformity in the level of control exercised by countries that take the responsibility of inspections seriously, as shown in the two preceding graphs, this is seen even more clearly in the comparison of the percentages of detentions. Some of the cases, but not all, are seen to be quite significant.

Based on a simple cluster analysis (the unweighted pair-group method using arithmetic average UPGMA (Ludwig *et al.*, 1988) (Sneath *et al.*, 1973) (Dillon *et al.*, 1984), using the standardized variables: number of inspections, detentions, and deficiencies), we shall determine the results that are shown in the following dendogram (Figure 2).

In order to determine some relevant aspects of the relationship of these variables, and by means of a Multidimensional scaling (MDS) we shall obtain a representation of two dimensions of the similarity of the observed countries.

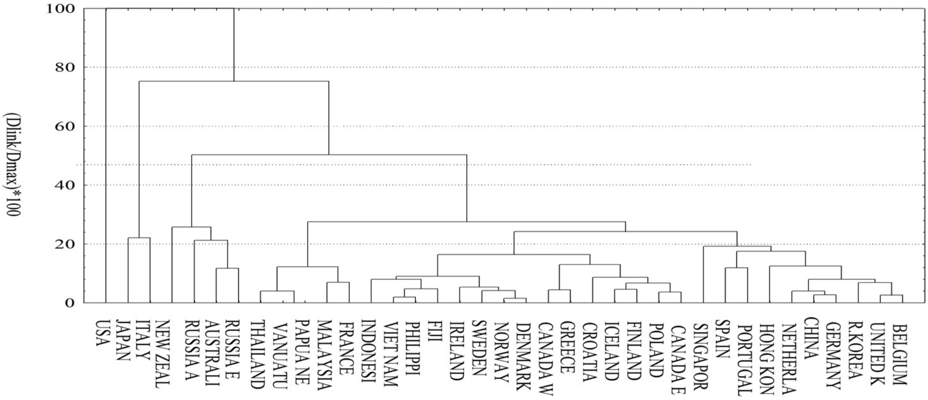


Fig.2: Dendogram.

Two previous conclusion can be drawn from these results:

a) Those countries that are relatively rigorous in their control, such as the USA, generate a degree of self-control on the part of shipowners, in self-protection. Although the USA maintains a reasonable rate of inspection – 22% - the rate of detentions is relatively low, representing 250 ships detained from a total of 11,000 inspections. A similar result occurs in Europe, with Sweden, but with much lower totals. In Australia and New Zealand, a similar situation can be seen.

b)The number of detentions shoots up when two factors come into play: a high rate of inspections and the habitual presence of substandard ships. A typical case of this is Greece, where the level of detentions in 1999 was more than 21%.

Typology of ship detentions.

The detentions represent the most important part of the wider scope of the instruments of control. Therefore two basic initial questions arise: What is the predominant basic deficiency for which substandard ships are detained? and What types of ship are most frequently detained?

The answer to the first is that deficiencies under the safety provisions are numerically the most significant; these divide into three main groups: 1) those referring to survival and life-saving equipment; 2) those related to elements of the fire-fighting systems on board; and 3) those classified as "deficiencies of safety in general"[4]. One of the most striking figures is from the MoU of Paris, in which 96.75% of all ships with deficiencies have some deficiency in their life-saving equipment. Also significant are the deficiencies detected in Navigation systems: navigation equipment, radar, giro-compass, navigation lights and signals (COLREG), as well as in respect of charts and nautical publications.

The foregoing are the most significant of the total deficiencies. These are followed by non-compliance with Annexe I of the MARPOL: hydrocarbons record book, bilge separators, oleometers, etc. These levels of deficiency can be observed quantitatively in Table 4 (from which have been eliminated the deficiencies of minor significance).

Although there exists a clear similarity between the MoU's of París and Tokyo in respect of which groups of deficiency are most important, in the case of the PSC inspections carried out by the USCG, the group of "Operational deficiencies related to SOLAS" stands out from all the rest, being followed in importance by those of life-saving and fire-fighting equipment already mentioned. This finding indicates the importance that the North American inspectors attach to questions such as the Training Manual, emergency plans, instructions to the crew, skills of the crew in relation to safety operations, communication of safety, bridge routines,... all related to the operational compliance with the SOLAS Convention.

[4] In this section are included deficiencies related to: watertight doors, signing, servo-rudder, means of evacuation, electrical equipment, real and practice scale, etc.

	MoU Paris	MoU Tokyo
Certificates	3596	2204
Crew	1232	1234
Accommodation	1889	717
Stores And Galley	954	462
Life-Saving	10882	10266
Fire-Fighting Systems	8052	6407
Labour Risks	1336	521
Safety In General	7965	5550
Cargo Lines	3308	3844
Propulsion/Auxiliary Equipt.	2966	1555
Navigation	6643	5813
Radio Communications	2439	2504
Marpol Annexe I Deficiencies	4276	2944
Solas Operational Deficiencies	975	2641

Table 4: Number of deficiencies, by most important groups, in the MoU's of París and Tokyo.

Source: Authors' own, using data from the Reports of 1999 of the MoU's of París, Tokyo and the USCG.

	MoU Paris	MoU Tokyo	USCG USA
Bulk-carriers	442	195	74
Chemical tankers	55	22	4
Gas tankers	4	4	1
General cargo	849	611	119
Passenger	34	8	5
Refrigerated ships	37	48	-
RoRo/Containers	70	106	30
Other tankers	105	56	23
Other ships	88	21	1
TOTAL	1684	1071	257

Table 5: Number of PSC detentions by type of vessel

Quantitatively and despite talking of zones widely separated geographically, it is very surprising that in USA ports, where a high proportion of foreign-flagged ships are inspected, the number of detentions is very low, in comparison with those made under the European and Pacific agreements. The total numbers of PSC detentions in 1999 are very revealing.

— MoU París 1.684
— MoU Tokio 1.071
— USCG-USA 257

This could mean that the traditional demands of the USCG have given rise to a culture of safety that is imposed drastically on the ship-owners that decide to operate in US waters, independently of whether they may have opted to register under FOC. The breakdown of types of ship detained is as Table 5.

Influence of the Flag States on the detection of deficiencies

As methodology for a first comparative analysis of the possible relationship between FOC fleets and the detection of substandard ships, we shall take as a basis those flag fleets with the highest index of detentions under each of the MoU's studied: Table 6.

In spite of the divergence seen in the data under the two systems of control[5], it is evident that the ships on these three so-called "black lists" belong to FOC states. The correlation is therefore direct. Similarly, it is demonstrated that not all FOC have the same result in this particular ranking. It must be of great concern that the ships of the world's leading ship-registering state, Panama, which has over 100 mil-

MoU Paris	Albania; Honduras; Belice; Lebanon; Syria; Romania; Cambodia; Turkey; Georgia; Algeria; Libya; St.Vincent/Granada; Egypt; Morocco; Mauritius; Bangladesh; Ukraine; Malta; Pakistan; Cyprus; **Panama**; Malaysia; Cuba; Russia; Bulgaria; Thailand; Lithuania; Croatia; Azerbaijan.
MoU Tokyo	North Korea; Cambodia; Belize; Vietnam; Indonesia; Turkey; St.Vincent/Granada; Honduras; Malta; Thailand; Egypt; Russia; Iran; Antigua and Barbados; Malaysia; Cayman Islands; China; South Korea; Taiwan.
USCG-USA	Belice; Honduras; Venezuela; St.Vincent/Granada; Turkey; India; Cyprus; Vanuatu; Thailand; **Panama**; Malta; Russia; Antigua and Barbados; Philippines.

Table 6: Flag fleets with the highest index of detentions under each of the MoU's studied

lion GT under its flag, tables in two of these three black lists. However, it is also striking how another of the traditional FOC states, Liberia, or the relative newcomer, the Bahamas, are not found in the above but in the "white list" of the MoU of Paris, while countries that have actually signed the Memorandum itself, such as the Russian Federation, make up much of the black list. The utilization of Caribbean states like Belize, St. Vincent and Granada or the Cayman Islands, also demonstrates an arbitrary interpretation of the meaning of international responsibility on the part of some of these states.

Evolution and incidence of the instruments of control.

The importance of any of these instruments of control is based not only on its capacity for establishing lists that reflect the fleets that are most guilty of failure to comply with minimum safety provisions, but also on whether these instruments serve to create a culture of prevention, even of an aggressive position towards those who do not comply with the system of International Conventions.

In order to study the relationship between the following variables: inspection ships, detentions, number of inspections, number of deficiencies and year, we have obtained the following table 3. The table shows three numbers of each pair: Pearson coefficient of correlation, number (11) of years (period between 1991 and 2001) and p (when p is less than 0.05 implies that exists a significant correlation with a level of 95%).

The results of this table implies an important relationship in nearly every pair, with the only exception of ships and detentions. It would appear from the data in these reports that even though the level of inspections proposed has been achieved, this has not produced, as a general rule, any reduction in the numbers of deficiencies. In fact, the Pearson coefficient of correlation between the number of inspections and

[5] This consideration of "black flag" is different from that which we have seen throughout this Manual, but this has not stopped it from being referred to over very similar criteria. In the case of the MoU of París, the so-called "black list" has been considered calculated on the basis of a formula that takes into account the trend of detentions/inspections, in the MoU of Tokyo, the flags that exceed the average level of detentions, and for the USA, comprise their "priority list".

	Year	Inspections	Ships	Detentions	Deficiencies
Year		0.8746 11 0.0004	0.7495 11 0.0079	0.7825 11 0.0044	0.9268 11 0
Inspections			0.9189 11 0.0001	0.7066 11 0.0151	0.905 11 0.0001
Ships				0.4134 11 0.2063	0.7053 11 0.0153
Detentions					0.9223 11 0.0001

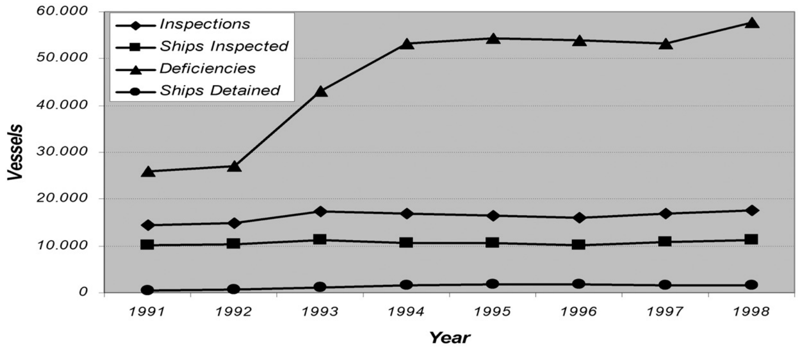
Table 7: Multivariate Analysis

the number of deficiencies is positive, meaning a direct relationship between the variables instead of an inverse relationship, which would be desirable. (Figure 4).

It can be observed how from the year 1992, coinciding with a series of significant accidents such as that of the "Aegean Sea" in Spanish waters, the European countries made a substantially increased effort in their inspections, greatly increasing the number of detentions by almost double, to reach annual totals of around 1,000 ships detained in waters under the MoU of Paris regime. The number of inspections and ships inspected has maintained a regularity that would comply with the minimum objective of 25%. Bearing in mind that the aim of the PSC system of control is the reduction of substandard ships, it seems that this is not being achieved, for several reasons (Pérez *el al.*, 2000):

1) The number of ships detained is not following a curve of decline.
2) The number of deficiencies detected is being maintained or even increasing year on year.
3) The countries with the more shipping movements are practically the same, thus the status of the substandard fleets remains unchanged, with the instruments of control failing to make any impression in fostering a culture of prevention.
4) The Classification Societies that act in the name of the governments of the FOC states are the same.

Perhaps, as some studies suggest, consideration should be given to the way in which the inspectors act, that is to say, inspections by non-selective sampling. This method would not meet the condition that all the equipment or systems of the ship should have the same probability of being checked. The operational control of the safety elements established in the SOLAS is pointed to as one of the keys to the



Source: Authors' own, from the Reports of the MoU 1999.

Fig.4: Comparison of: ships detained and nº of deficiencies in those inspected, and with the nº of inspections in the Memorandum of París between the years 1991-1999.

improvement of the system. This has occurred, as already commented, with the North American system of control, where the group of these deficiencies is seen to be predominant. This trend is also indicated in the Tokyo MoU.

Other causes of the ineffectiveness of the system, in respect of the professionalism in the detection of deficiencies, are the failure to keep instructions up-to-date and the absence of documented operative procedures for carrying out inspections. Uniform criteria for the treatment of deficiencies can and should be set by international organizations, or at least, by the regional ones, with responsibility for the PSC system. Do we need a European Agency for Maritime Safety, independent of the national Maritime Administrations? This could be a solution, accompanied by a European Standard, dealing with the technical competences of the bodies performing these inspections and incorporating the relevant requirements of the EN/ISO 9000 series of standards applicable to the quality control systems of inspection bodies (Pérez *el al.*, 2000).

CONCLUSIONS

Maritime transport has been shown to be one of the most ecological systems of the multi-modal chain of the 21st Century, but in spite of this, it is in a permanent state of crisis in respect of Maritime Safety. In fact, on many occasions, it raises genuine public alarm, particularly in the countries of the European Union. The globalization of trade and of the maritime transport sector itself makes it difficult to achieve the correct application of preventive policies on the part of those authorities with the competence and the means to do so: the Flag States of the ships. This abandoning of responsibilities has given rise to a reaction on the part of the Coastal States and Port Authorities, which is producing a progressive modification of international legislation. A further step has been taken with the approval of specific national regulations in the USA; these have even breached the previous international consensus on this subject.

The European Community law and the policies of the Commission are also tending in this direction. The universality of the PSC is evident by the appearance of a significant number of regional agreements between the Coastal States; however, in spite of this, the PSC is failing to remain universal and homogeneous. The North-South differences demonstrate systems that are incapable of applying the controls thatexist in the mechanisms already in force in the western countries. The system of regional Memoranda requires a homogeneous procedure that is uniformly effective and rigorous in the elements of control. The case of the tanker "Erika" is an example of the distrust existing between States members, which generates a centrifugal tendency in the implementation of regional policies, to the detriment of those favouring national action.

A similar jealousy already exists in other scenarios, for example where some are trying to emulate the North American system rather than consolidate the South American Agreement of Viña del Mar. Or the primacy of the oceanic countries (Australia and New Zealand) over the rest of the countries signatories of the Memorandum of Tokyo.

We might go beyond the flags of convenience and consider what are already beginning to be known as "ports of convenience" where a blind eye is turned by the authorities with the aim of favouring the competitivity of their port. This occurred in Europe in the rivalry between Belgium and Holland, and may represent yet another phenomenon of "every man for himself" in the so-called global jungle.

For we should not fool ourselves. We should realize that, in reality, the evolution of the problem will lead to more satisfactory results when more investments are made by the leading countries towards these purposes. The example of the US Coastguards is most significant: this can be considered the PSC system that provokes the most "fear" among the owners and operators of substandard ships, who as a result either choose to improve the level of their vessels or else deploy them in other maritime zones, in order to avoid submitting to the USCG degree of control.

In short, we in Europe at least, are faced with a system that, as we have described and tried to analyse in detail, does not reduce the number of deficiencies in the safety of vessels – vessels that are themselves frequently deficient. Neither does this system reduce the accident rate; it has repercussions on political actions, at times demagogic; and it does not always respond to technical measures that are necessary. This is the case of the perfunctory implementation of the double hull in Europe, as if this were a universal panacea, and as if once this were implemented, no other serious problems would exist, such as the vitally important training of merchant seamen, or the management of emergency situations on board ships, or the necessary professionalisation of a competent Maritime Administration in all the coastal states of Europe.

Only the awareness of individual citizens and the global management of the problem under the authority of the International Maritime Organisation will enable this situation to be properly dealt with. The dangers and risks faced, which should never be minimised for obvious reasons, at least demand much more rigorous regulation in order to protect the natural environment, which in the last analysis is the best legacy that today's society can bequeath to future generations.

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EL CONTROL DE LA SEGURIDAD MARÍTIMA EN LA ERA DE LA GLOBALIZACIÓN.

RESUMEN

Por más de 30 años la Organización Marítima Internacional ha llevado a cabo un gran esfuerzo por desarrollar un cuerpo legislativo importante para el aseguramiento de unos mínimos de seguridad y protección del entorno marítimo. Los Convenio SOLAS y MARPOL han sido adoptados por la normativa internacional en un porcentaje superior al noventa por ciento de la flota. A pesar de ello la realidad contradice esta situación con hechos significativos como la aparición de buques "sub-standard" y la proliferación de los registros abiertos con un déficit considerable en la seguridad de la navegación marítima. Son muchos los países que se involucran en la mejora de esta situación, por una parte los estados de bandera pero también de forma significativamente creciente, los estados costeros o portuarios que sufren los efectos de un siniestro, especialmente desde el punto de vista de la contaminación de su entorno marino. El Memorandum de Paris firmado en el año 1982 y otros acuerdos regionales son ejemplos de una nueva política de control del estado rector del puerto for been considering the implementation of(Port State Control PSC). El propósito de este artículo es analizar la efectividad de estos mencionados sistemas de control y estudiar la influencia de estas políticas especialmente en lo referente a los pabellones de conveniencia.

Palabras claves: Transporte Marítimo, Seguridad, Globalización

INTRODUCCIÓN.

El transporte marítimo es una herramienta del sistema económico occidental. A fuerza de ser críticos tenemos que asumir que el Mundo occidental utiliza en más de un 40%, el petróleo como fuente de energía primaria. A pesar de ello el transporte marítimo sigue siendo, desde el punto de vista ambiental, el menos nocivo en su relación de distancia/carga. Así mismo existe una trayectoria internacional importante, de consenso internacional en la regulación de la seguridad de la navegación. En los últimos treinta años se ha duplicado la demanda de este tipo de transporte. En el transporte de crudo y productos del petróleo tenemos que hablar de un aumento del 50% en el mismo periodo de tiempo. Pero la foto fija de la flota mundial presenta un panorama nada halagüeño: en definitiva "barcos viejos", con una media que no abandona los veinte años desde su construcción y bajo un sistema establecido de banderas de conveniencia que constituyen el lugar reservado para el abrigo de los buques "substandards". Mientras la flota mundial crece, la flota abanderada en EE.UU. o los países de la Unión asisten a un goteo continuo que reduce su flota año por año.

El buque subestandard es el cancer de la industria marítima pués es en gran parte el origen de sus problemas. Y el primero de los problemas surge de la reducción de costes de algunos navieros en detrimento de la seguridad de los buques, materializado en el empleo de pabellones de conveniencias.

EVOLUCIÓN DE LOS INSTRUMENTOS DE CONTROL POR ESTADO RECTOR DEL PUERTO.

El Control del Estado Rector de Puerto (*Port State Control*), consiste en la inspección de buques extranjeros en puertos nacionales, con el propósito de verificar que las condiciones del buque, su equipo, y su tripulación cumplen con los requisitos exigidos en los Convenios Internacionales. El origen de este sistema de inspecciones debemos buscarlo en un problema en el que la Organización Marítima Internacional (IMO), desde su constitución, ha concentrado sus esfuerzos: asegurar que todos los buques cumplen con unos requisitos mínimos para que no constituyan un peligro para la navegación segura, así como para garantizar que las condiciones de vida de sus tripulantes son aceptables.

BUQUES SUBSTANDARDS Y PABELLONES DE CONVENIENCIA.

Hasta la década de los setenta la peligrosidad manifiesta del transporte marítimo no suponía una alarma social como la desencadenada por los sucesos posteriores, que han jalonado una lista interminable de nombres de buques como "Amoco Cádiz", "Exxon Valdez", "Mar Egeo" o "Erika". Consecuentemente la proliferación de banderas de conveniencia (FOC) ya no suponía sólo la desviación de fondos fiscales desde los países desarrollados a otros, que con el objeto de obtener una fuente de divisas prestaban sus pabellones a los armadores del primer Mundo, sino que esta práctica desencadena un fenómeno de buques subestandards con las características de todos conocidas: equipamiento en seguridad insuficiente, tripulaciones con un perfil de formación deficiente, control inefectivo por parte de los Estados de pabellón. Todo ello ha constituido un peligro latente en cuanto a siniestrabilidad marítima en las costas de los Estados receptores del tráfico marítimo mundial. Frente al elemento negativo del *"flagging out"*, cabe destacar un proceso inverso de control que en los últimos años ha propiciado una auténtica revolución del Derecho del Mar, al objeto de cubrir una laguna que hiciera imposible el incumplimiento de los niveles mínimos de seguridad en los buques. Al objeto de analizar cuál ha sido el nivel de efectividad del sistema de control de los Estados ribereños hemos tomado como partida los siguientes Informes:

— *Annual Report MoU Paris (+Blue Book).*
— *Annual Report on PSC in the Asia-Pacific Region (+PSC Report Australia).*
— *Port State Control Report U.S.Coast Guard.*

CONCLUSIONES.

El transporte marítimo a pesar de revelarse como uno de los sistemas más ecológicos de la cadena multimodal del siglo XXI, supone desde el punto de vista de la Seguridad Marítima un elemento en crisis permanente y que levanta en ya numerosas ocasiones una auténtica alarma social, especialmente en los países que conforman la Unión Europea. La globalización del comercio y del propio negocio marítimo dificulta la correcta aplicación de políticas preventivas por parte de aquellos que cuentan con la competencia y los medios: los Estados del pabellón de los buques. Esta dejación de responsabilidades origina una reacción por parte de los Estados ribereños y rectores de puerto, que desemboca en una progresiva modificación de la legislación internacional. Un paso más se da con la aprobación de determinadas regulaciones nacionales en los EE.UU. que llegan incluso a romper el consenso internacional en esta materia. El Derecho comunitario y las pretensiones de la Comisión van también en este sentido. La universalidad del PSC es evidente por la aparición de un importante número de acuerdos regionales entre los Estados ribereños, sin embargo, y a pesar de ello, deja de ser universal y homogéneo. Las diferencias Norte-Sur ponen de manifiesto sistemas incapaces de asumir los controles que existen en los mecanismos vigentes en los países occidentales. El sistema de Memorandums regionales requiere de un procedimiento homogéneo de igual rango en efectividad y rigurosidad en los elementos de control. El caso del buque tanque "Erika" es un ejemplo de la desconfianza entre Estados miembros, que genera una tendencia centrífuga en la implantación de políticas regionales en detrimento de los partidarios de acciones nacionales. El mismo recelo que ya existe, por ejemplo, en otros escenarios, que pretenden emular el sistema norteamericano en vez de consolidar el Acuerdo Suramericano de Viña del Mar. O la primacía de los países oceánicos (Australia o Nueva Zelanda) sobre el resto de los países que componen el Memorandum de Tokio. Podemos ir más allá de los pabellones de conveniencia e inventarnos los que ya empiezan a conocerse como puertos de conveniencia en manifiesta alusión a los Estados donde se hace la "vista gorda", pretende favorecer la competitividad del puerto. Ocurrió en Europa entre Bélgica y Holanda y puede suponer un fenómeno más del "sálvese quién pueda" de la llamada jungla global. Porque no nos engañemos y pensemos que en realidad, la evolución del problema resulta más satisfactoria cuanto más sea la inversión económica que los países destinen a estos fines: el caso del Guardacostas de los EE.UU. es el más significativo, puede considerarse como el sistema de PSC que genera más "temor" frente a los armadores de buques substandards, que optan por mejorar el nivel de sus barcos o bien destinarlos a otras zonas marítimas donde poder eludir la acción de control. En definitiva estamos, al menos en Europa, ante un sistema, que hemos intentado analizar con detalle, que si bien identifica, no reduce, el número de deficiencias de seguridad en los buques, ya de por sí deficientes. Tampoco reduce la siniestrabilidad, y que repercute en actuaciones políticas, a veces demagógicas y que no siempre responden a medidas técnicamente necesarias. Es el caso de la implantación "a la ligera" del doble casco en Europa, como si eso fuera la panacea universal, y como si a partir de ese momento no existieran problemas tan importantes como la formación de los marinos o la gestión de situaciones de emergencias a bordo de los buques, o a la necesaria profesionalización de una Administración Marítima competente en todos los estados ribereños europeos. Sólo la conciencia de los ciudadanos y la gestión global del problema desde el punto de vista de la Organización Marítima Internacional, permitirá hacer frente a una situación que nunca podrá ser minimizada por razones naturales, pero que sí al menos requerirá de una regulación más severa en pro de la protección del medio ambiente, que al fin y al cabo es la mejor de las herencias para las futuras generaciones.

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COMBUSTION PROCESS IMPROVEMENT IN A MARINE DIESEL ENGINE

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ABSTRACT

This paper presents the modifications carried out on a four years running medium-speed four-stroke propulsion diesel engine for improving its combustion process in order to avoid the damages produced at the piston crowns by the injected fuel jets. The works were carried out under instructions from Wärtsilä NSD using a technology developed by this maker focused to decrease the emissions of soot particles and nitrogen oxides (NOx) without affecting the specific fuel consumption of new production engines and also for upgrading older engines still in operation. Various running parameters were checked before and after modifications while the ship was underway in normal sailing conditions. The values obtained were then compared to find out the results that might be inferred from such modifications

Keywords: marine engines, internal combustion engines, diesel engines, combustion, environmental impact.

INTRODUCTION

The subject of this study is a medium-speed four-stroke propulsion diesel engine which design parameters have been modified while remained installed in the reefer containership *Carmen Dolores H.*

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Figure 1: Containership Carmen Dolores H. Source: fieldwork

This engine is a Wärtsilä VASA 9R46B, supercharged and fitted with a fuel oil solid injection system. It drives a shaft generator, a controllable pitch propeller and has the following particulars:

The compression ratio resulting of the compression stroke is determined in this engine by a supplement plate placed between every connecting rod and its big end. Every cylinder liner is provided with an anti-polishing ring on its upper end in order to prevent formation of coal deposits around the piston crown. The supercharging is carried out using the SPEX system, therefore the engine is fitted with a by-pass at the exhaust manifold and a relief valve, called waste gate. This arrangement enables an efficient work of the turbocharger under low engine loads and avoids an excessive exhaust pressure at loads over 85% the rated power by reducing the flow of gases to the turbocharger turbine by means of the by-pass.

Another interesting feature of this engine is the twin-injection system. There are two fuel valves in the cylinder head. A main injector located in the centre of the cylinder head is preset at 450 bars. A pilot injector preset at 320 bars is placed in the cylinder head side and arranged tilted at an angle of 45º. This injector facilitates a pre-mixture burning with smaller ignition delay, which results into a smaller peak pressure and temperature in the cylinder and at last into a small NOx emission.

The decision for improving the behaviour of the engine was imposed by the fact that at every overhaul carried out since the ship began to sail all piston crowns had shown marks corresponding to the fuel jets leaving the orifices of the main injector [*Figure 2*]. The loss of substance in such marks had reached depths up to 3 mm.

Output: 8,775 kW	Number of cylinders: 9 in line
Service speed: 500 rpm	Piston stroke: 580 mm
Cylinder bore: 460 mm	Compression ratio: 12.5:1
Max. compression pressure: 130 bar	Max. combustion pressure: 180 bar
Supercharging air pressure: 3.1 bar	Mean effective pressure: 24.3 bar
Fuel: heavy fuel oil IFO 180	Year of building: 1993

Table 1. Engine particulars Source: fieldwork

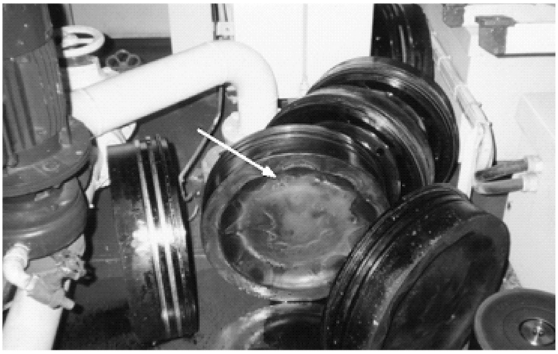

Figure 2: Damaged piston crowns Source: fieldwork

The engine upgrading was carried out under instructions from Wärtsilä NSD in order to obtain an improvement of the combustion process avoiding the damages produced by the injection fuel jets on the piston crowns, a smaller quantity of soot particles and NOx exhausted, a smaller thermal charge of the combustion chamber components, a lower specific fuel consumption at partial loads, a lower turbocharger speed at partial loads, and a higher supercharging air pressure at loads near full power.

METHODS

The following works were carried out for upgrading the engine:

— Modification of the anti-polishing ring
— Replacement of the 5.0 mm thick supplement plates between connecting rods and big ends by new supplements with a thickness of 11.0 mm
— Decrease of the injection start advance from 15.3° to 12.2°
— Renewal of the piston crowns
— Gathering of performance data before and after the mechanical works

We have gathered the performance data while the ship was underway in normal sailing conditions; that is to say, with the engine at a steady speed of 500 rpm and developing any power between 80-85% the rated power, as per the condition of sea and weather. The parameters taken into account for the gathering of data were: engine rpm, turbocharger rpm, supercharging air pressure, engine load, compression pressure at ignition start in every cylinder, maximum pressure in every cylinder, mean pressure in every cylinder, exhaust temperature at every cylinder, exhaust temperature before turbocharger, temperature of main bearings, engine fuel consumption and ship speed.

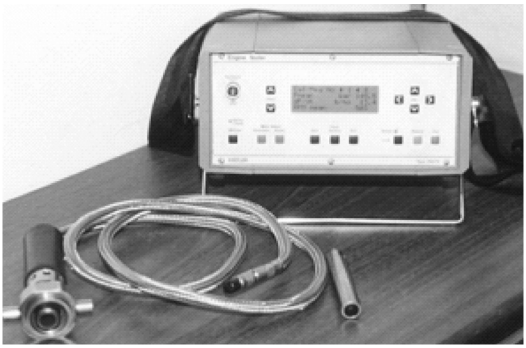

Figure 3: Engine Tester 2507A Source: fieldwork

The gathering and processing of the combustion pressures were carried out using the portable instrument made by

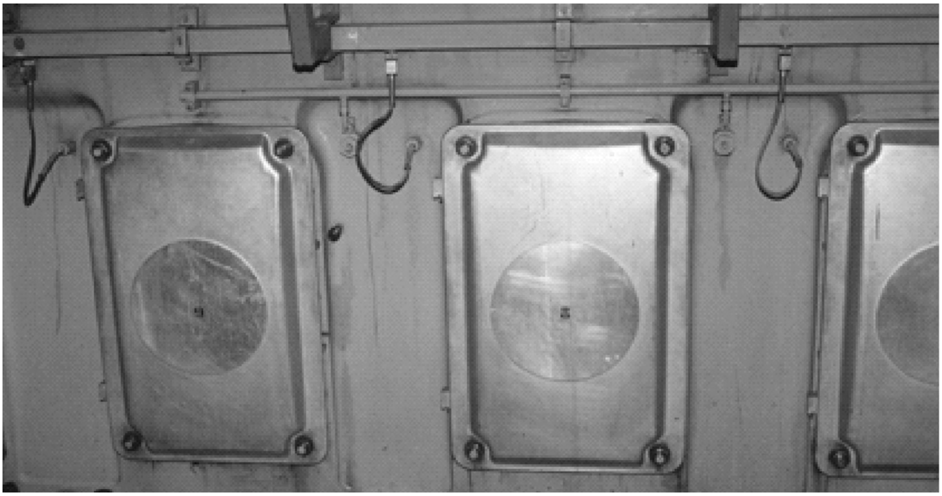

Figure 4: Permanent wiring for main bearing temperature monitoring Source: fieldwork

Klister Instrument AG named Engine Tester type 2507A, shown in *Figure 3* with the pressure sensor to be connected with the indicator cock of every cylinder.

The temperature of every main bearing was obtained using the engine monitoring system, fitted for such purpose with permanent temperature sensors and electrical wiring [*Figure 4*].

In order to find out the results of the above-cited modifications we have compared the value of the various performance data checked before and after them. The following two graphs show values pertaining to the number 5 cylinder. In *Figure 5* are shown the values obtained for compression pressure at ignition start and for maximum pressure. At the upper zone of the graph appear stated the maximum pressures, while at its lower zone are the compression pressures. The values taken after modification appear at the load range from 83% to 85%, meaning more steady conditions of sea and weather than when taken before the engine modification.

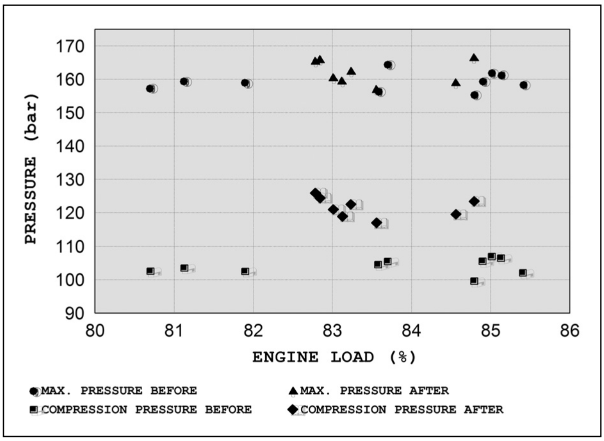

Figure 5: Nr 5 cylinder maximum pressure and compression pressure

Like was found out for the other eight cylinders

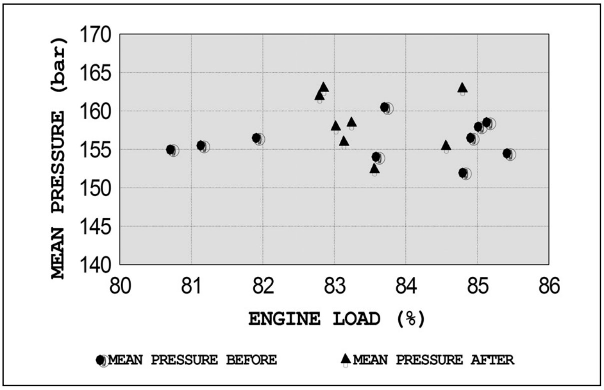

Figure 6: Nr 5 cylinder mean pressure Source: fieldwork

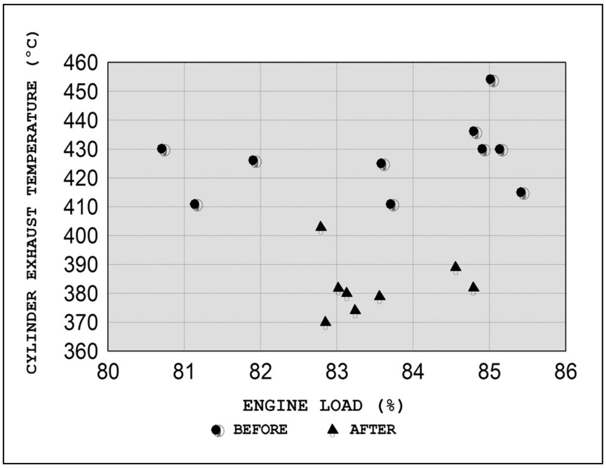

Figure 7: Nr 5 cylinder exhaust temperature Source: fieldwork

of the engine, this graph shows that the compression pressure at ignition start has suffered a significant increase reaching a mean value of 15.7 bar. The replacement of the 5.0 mm thick supplement plates between connecting rods and big ends by new supplements with a thickness of 11.0 mm has resulted in an increase of the compression ratio and the consequent increase of the compression pressure at ignition start.

On the contrary, the maximum pressure of the working cycle after the modification has not varied in respect to the value found out before it, despite the decrease of the injection start advance from 15.3º to 12.2º. Similar results have been found out for the other eight cylinders of the engine.

Figure 6 shows the values obtained for the mean pressure in the number 5 cylinder also. The mean pressure before the engine modification ranged from 152 to 160 bar and after the modification ranges from 152 to 163 bar, which means no significant variation. Similar ranges were obtained for the other eight cylinders of the engine.

Figure 7 shows the values obtained for the number 5 cylinder exhaust temperature. Like obtained for the other eight cylinders, this graph shows that such temperature is lower after modification than before it.

Figure 8 shows the mean values obtained for the temperature of the engine main bearings. Such values are lower after the modification than before it reflecting that the bearings are suffering a lower thermal charge.

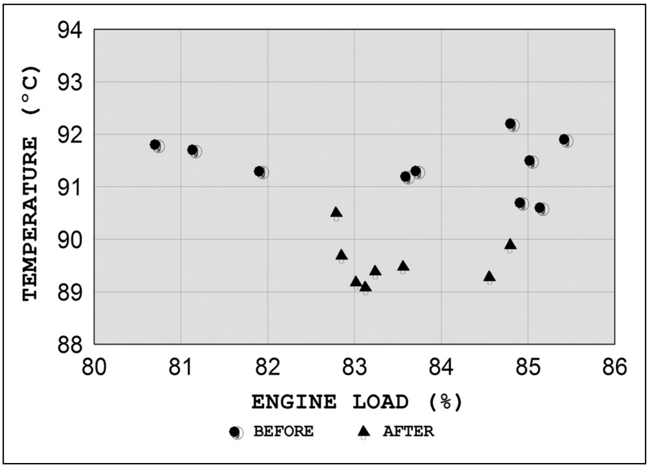

Figure 8: Mean temperature of the engine main bearings

Source: fieldwork

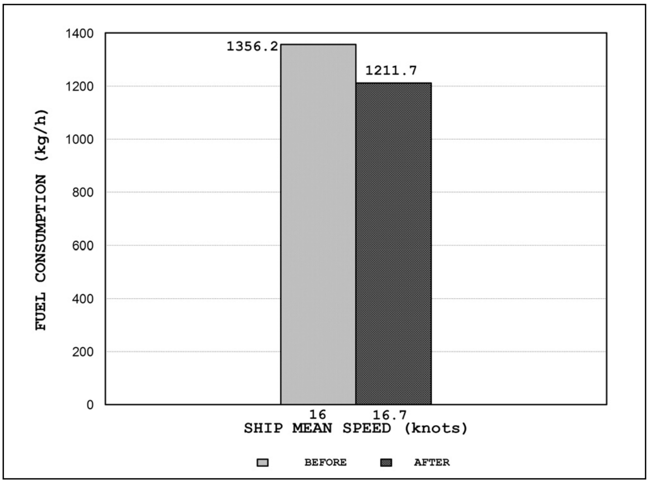

Figure 9: Fuel consumption

Source: fieldwork

The values obtained for the fuel consumption of the engine under normal sailing conditions are lower after the modification than before it and are shown in *Figure 9*, where the ship mean speed has been stated also.

In addition to this lower fuel consumption we have considered another two meaning facts: the former that the gases exhausted through the funnel observed with the naked eye seem to be more clear than before the modification of the engine, the latter that piston crowns have appeared in good condition at the overhauls carried out after the modification, without the damages produced by the fuel jets shown in *Figure 2*.

CONCLUSIONS

— The increase of compression pressure at ignition start with the subsequent increase of temperature at ignition start have resulted in an improved combustion, crisper and faster, without damages by fuel jets on the piston crowns and a lower emission of pollutants with the exhaust gases.

— This improved combustion has resulted in an upgraded efficiency of the engine with a lower thermal charge in its main bearings and a lower fuel consumption.

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MEJORA DEL PROCESO DE COMBUSTIÓN EN UN MOTOR DIESEL MARINO

Resumen

Este artículo presenta las modificaciones realizadas en un motor diesel propulsor de cuatro tiempos semi-rápido con cuatro años de funcionamiento instalado en el portacontenedores frigorífico Carmen Dolores H.; a fin de mejorar el proceso de combustión para evitar los daños producidos en las cabezas de los pistones por los chorros de combustible inyectado. Los trabajos se efectuaron según instrucciones de Wärtsilä NSD, usando una tecnología desarrollada por este constructor enfocada a disminuir las emisiones de partículas de hollín y de óxidos de nitrógeno, sin afectar el consumo específico de combustible tanto en los motores de nueva construcción como también para mejorar motores más antiguos aún en funcionamiento.

El motor es un Wärtsilä VASA 9R46B, de 8.775 Kw a 500 rpm, 9 cilindros en línea que acciona un generador de cola y una hélice de paso variable. El grado de compresión está determinado en ese motor por una chapa de suplemento ubicada entre cada biela y su cabeza. Cada camisa está dotada con un aro anti-pulido en su parte superior para evitar la formación de depósitos alrededor de la cabeza del pistón. La sobrealimentación se realiza por el sistema SPEX, estando dotado por tanto en el colector de escape de una válvula de alivio y un by-pass que reduce el flujo de gases hacia la turbo a cargas superiores al 85 % de la nominal. Cada cilindro está dotado de dos inyectores de combustible: un inyector principal en el centro de la culata y un inyector piloto en su costado, inclinado 45º y con menor presión de timbre que el principal. Las cabezas de los pistones venían mostrando daños con pérdida de material de hasta 3 milímetros de profundidad en zonas alcanzadas por los chorros de combustible procedentes del inyector principal.

METODOLOGÍA

Se realizaron los siguientes trabajos: modificación del aro anti-pulido, sustitución del suplemento de 5,0 mm de grosor existente entre cada biela y su cabeza por otro de 11,0 mm, disminución del avance a la inyección de 15.3º a 12.2º, renovación de las cabezas de los nueve pistones y acopio de datos de funcionamiento antes y después de los trabajos de mecánica.

Hemos acopiado los datos de funcionamiento con el buque navegando en condiciones normales; o sea, con el motor a una velocidad estable de 500 rpm y desarrollando cualquier potencia entre el 80 y el 85% de la nominal, según el estado de la mar y el tiempo. Los parámetros contemplados para el acopio de datos fueron: revoluciones por minuto del motor y de la turbo, presión del aire de sobrealimentación, carga del motor, de cada cilindro: presión de compresión al comienzo de la ignición, presión máxima, presión media y temperatura de escape; temperatura de los gases de escape antes de la turbo, temperatura de los cojinetes de bancada del motor, consumo de combustible de éste y la velocidad del buque.

El acopio y procesado de las presiones de combustión se realizó usando un equipo portátil Engine Tester 2507A de Klister Instrument AG con el correspondiente sensor de presión para conexión con el grifo del indicador de cada cilindro. La temperatura de los cojinetes de bancada se obtuvo usando el sistema de monitorización del motor, dotado a tal efecto de una instalación permanente de sensores de temperatura y cableado.

Hemos encontrado que después de realizar las modificaciones en el motor, la presión de compresión al comienzo de la ignición ha experimentado un aumento significativo, alcanzando un valor medio de 15.7 bar. La sustitución de los suplementos de 5,0 mm entre las bielas y sus cabezas por otros de 11,0 mm de grosor ha dado como resultado un aumento del grado de compresión y el consiguiente incremento de la presión de compresión al comienzo de la ignición. Por el contrario, el valor de la presión máxima del ciclo de trabajo no ha variado después de las modificaciones respecto al valor obtenido antes, a pesar de la disminución del avance a la inyección de 15,3º a 12.2º. La presión media antes fluctuaba de 152 a 160 bar y después de las modificaciones fluctúa de 152 a 163 bar, lo que no representa una variación significativa.

Las temperaturas de escape de los cilindros son menores después de las modificaciones que antes. Lo mismo ocurre con las temperaturas de los cojinetes de bancada del motor, reflejando que la carga térmica que soportan es menor. También es menor el consumo específico de combustible después de las modificaciones. Además de este menor consumo de combustible, hemos considerado otros dos hechos significativos: que los gases evacuados por la chimenea del buque parecen más claros a simple vista, y que las cabezas de los pistones han aparecido en buen estado en las revisiones realizadas después de las modificaciones.

CONCLUSIONES

— El aumento de la presión de compresión al comienzo de la ignición con el consiguiente aumento de la temperatura ha dado como resultado una mejor combustión, más enérgica y rápida, sin daños por chorros de combustible sobre las cabezas de los pistones y con una menor emisión de contaminantes con los gases de escape.

— Esta combustión mejorada ha dado como resultado un rendimiento mejorado del motor, con una carga térmica menor en sus cojinetes de bancada y un menor consumo específico de combustible.

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THE ENERGY CHALLENGE... THE HYDROGEN

F. Arvelo[1] and I. Padrón[2]

ABSTRACT

Energy is the very lifeblood of today's society and economy. Our work, leisure, and our economic, social and physical welfare all depend on the sufficient, uninterrupted supply of energy. Yet we take it for granted – and energy demand continues to grow, year after year. Traditional fossil energy sources such as oil are ultimately limited and the growing gap between increasing demand and shrinking supply will, in the not too distant future, have to be met increasingly from alternative primary energy sources. We must strive to make these more sustainable to avoid the negative impacts of global climate change, the growing risk of supply disruptions, price volatility and air pollution that are associated with today's energy systems. The energy policy of the European Commission(1) advocates securing energy supply while at the same time reducing emissions that are associated with climate change. This calls for immediate actions to promote greenhouse gas emissions-free energy sources such as renewable energy sources, alternative fuels for transport and to increase energy efficiency.

On the technology front, hydrogen, a clean energy carrier that can be produced from any primary energy source, and fuel cells which are very efficient energy conversion devices, are attracting the attention of public and private authorities. Hydrogen and fuel cells, by enabling the so-called hydrogen economy, hold great promise for meeting in a quite unique way, our concerns over security of supply and climate change.

The report highlights the need for strategic planning and increased effort on research, development and deployment of hydrogen and fuel cell technologies.

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It also makes wideranging recommendations for a more structured approach to European Energy policy and research, for education and training, and for developing political and public awareness. Foremost amongst its recommendations is the establishment of a European Hydrogen and Fuel Cell Technology Partnership and Advisory Council to guide the process.

Key words: energy, hydrogen, the environment

FOREWORD

Worldwide demand for energy is growing at an alarming rate. The European "World Energy Technology and Climate Policy Outlook" (WETO) predicts an average growth rate of 1.8% per annum for the period 2000-2030 for primary energy worldwide. The increased demand is being met largely by reserves of fossil fuel that emit both greenhouse gasses and other pollutants. Those reserves are diminishing and they will become increasingly expensive. Currently, the level of CO_2 emissions per capita for developing nations is 20% of that for the major industrial nations. As developing nations industrialise, this will increase substantially. By 2030, CO_2 emissions from developing nations could account for more than half the world CO_2 emissions. Industrialised countries should lead the development of new energy systems to offset this.

Energy security is a major issue. Fossil fuel, particularly crude oil, is confined to a few areas of the world and continuity of supply is governed by political, economic and ecological factors.

These factors conspire to force volatile, often high fuel prices while, at the same time, environmental policy is demanding a reduction in greenhouse gases and toxic emissions.

A coherent energy strategy is required, addressing both energy supply and demand, taking account of the whole energy lifecycle including fuel production, transmission and distribution, and energy conversion, and the impact on energy equipment manufacturers and the end-users of energy systems. In the short term, the aim should be to achieve higher energy efficiency and increased supply from European energy sources, in particular renewables. In the long term, a hydrogen-based economy will have an impact on all these sectors. In view of technological developments, vehicle and component manufacturers, transport providers, the energy industry, and even householders are seriously looking at alternative energy sources and fuels and more efficient and cleaner technologies – especially hydrogen and hydrogen-powered fuel cells.

In this document, highlights the potential of hydrogen-based energy systems globally, and for Europe in particular, in the context of a broad energy and environment strategy. It then proposes research structures and actions necessary for their development and market deployment.

Why hydrogen ?

A sustainable high quality of life is the basic driver for providing a clean, safe, reliable and secure energy supply in Europe. To ensure a competitive economic environment, energy systems must meet the following societal needs at affordable prices:

— *Mitigate the effects of climate change;*
— *Reduce toxic pollutants; and*
— *Plan for diminishing reserves of oil.*

Failure to meet these needs will have significant negative impacts on:

— *the economy;*
— *the environment; and*
— *public health.*

Measures should therefore be introduced which promote:

— *more efficient use of energy; and*
— *energy supply from a growing proportion of carbon-free sources.*

The potential effects of climate change are very serious and most important of all, irreversible. Europe cannot afford to wait before taking remedial action, and it must aim for the ideal – an emissions-free future based on sustainable energy. Electricity and hydrogen together represent one of the most promising ways to achieve this, complemented by fuel cells which provide very efficient energy conversion.

Hydrogen is not a primary energy source like coal and gas. It is an energy carrier. Initially, it will be produced using existing energy systems based on different conventional primary energy carriers and sources. In the longer term, renewable energy sources will become the most important source for the production of hydrogen. Regenerative hydrogen, and hydrogen produced from nuclear sources and fossil-based energy conversion systems with capture, and safe storage (sequestration) of CO_2 emissions, are almost completely carbon-free energy pathways.

Producing hydrogen in the large quantities necessary for the transport and stationary power markets could become a barrier to progress beyond the initial demonstration phase. If cost and security of supply are dominant considerations, then coal gasification with CO_2 sequestration may be of interest for large parts of Europe. If the political will is to move to renewable energies, then biomass, solar, wind and ocean energy will be more or less viable according to regional geographic and climatic conditions.

For example, concentrated solar thermal energy is a potentially affordable and secure option for large-scale hydrogen production, especially for Southern Europe. The wide range of options for sources, converters and applications, shown in Figures 1 and 2, although not exhaustive, illustrates the flexibility of hydrogen and fuel cell energy systems.

Fuel cells will be used in a wide range of products, ranging from very small fuel cells in portable devices such as mobile phones and laptops, through mobile applications like cars, delivery vehicles, buses and ships, to heat and power generators in stationary applications in the domestic and industrial sector. Future energy systems will also include improved conventional energy converters running on hydrogen (e.g. internal combustion engines, Stirling engines, and turbines) as well as other energy carriers (e.g. direct heat and electricity from renewable energy, and biofuels for transport).

The benefits of hydrogen and fuel cells are wide ranging, but will not be fully apparent until they are in widespread use. With the use of hydrogen in fuel-cell systems there are very low to zero carbon emissions and no emissions of harmful ambient air substances like nitrogen dioxide, sulphur dioxide or carbon monoxide. Because of their low noise and high power quality, fuel cell systems are ideal for use in hospitals or IT centres, or for mobile applications. They offer high efficiencies which are independent of size. Fuel-cell electric-drive trains can provide a significant reduction in energy consumption and regulated emissions. Fuel cells can also be used as Auxiliary Power Units (APU) in combination with internal combustion engines, or in stationary back-up systems when operated with reformers for on-board conversion of other fuels – saving energy and reducing air pollution, especially in congested urban traffic.

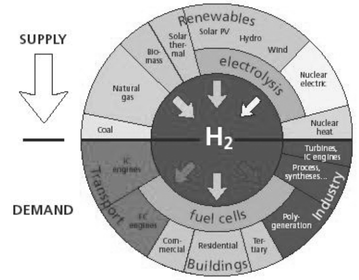

Figure 1: Hydrogen: primary energy sources, energy converters and applications

In brief, hydrogen and electricity together represent one of the most promising ways to realise sustainable energy, whilst fuel cells provide the most efficient conversion device for converting hydrogen, and possibly other fuels, into electricity. Hydrogen and fuel cells open the way to integrated "open energy systems" that simultaneously address all of the major energy and environmental challenges, and have the flexibility to adapt to the diverse and intermittent renewable energy sources that will be available in the Europe of 2030.

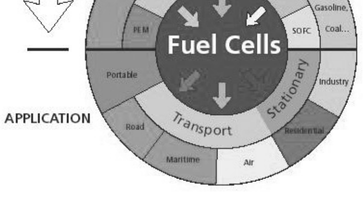

Figure 2: Fuel cell technologies, possible fuels and applications

PEM = *Proton Exchange Membrane Fuel Cell;*

AFC = *Alkaline Fuel Cells;*

DMFC = *Direct Methanol Fuel Cell;*

PAFC = *Phosphoric Acid Fuel Cell;*

MCFC = *Molten Carbonate Fuel Cell;*

SOFC = *Solid Oxide Fuel Cell*

Europe should lead in undertaking rational analysis of alternative energy options and in demonstrating the benefits of a transition to a widespread use of hydrogen and fuel cells. They will have to provide cost-effective solutions to the following key challenges – the main drivers for Europe's future energy systems.

Energy security and supply

Today's society depends crucially on the uninterrupted availability of affordable fossil fuels which, in future, will be increasingly concentrated in a smaller number of countries – creating the potential for geopolitical and price instability. Hydrogen opens access to a broad range of primary energy sources, including fossil fuels, nuclear energy and, increasingly, renewable energy sources (e.g. wind, solar, ocean, and biomass), as they become more widely available. Thus, the availability and price of hydrogen as a carrier should be more stable than any single energy source. The introduction of hydrogen as an energy carrier, alongside electricity, would enable Europe to exploit resources that are best adapted to regional circumstances.

Hydrogen and electricity also allow flexibility in balancing centralised and decentralised power, based on managed, intelligent grids, and power for remote locations (e.g. island, and mountain sites). Decentralised power is attractive both to ensure power quality to meet specific customer needs, as well as reducing exposure to terrorist attack. The ability to store hydrogen more easily than electricity can help with load levelling and in balancing the intermittent nature of renewable energy sources. Hydrogen is also one of the few energy carriers that enables renewable energy sources to be introduced into transport systems.

Economic competitiveness

Since the first oil crisis in the 1970s, economic growth has not been directly linked with growth in energy demand in the industrial sector, whereas in the transport sector increased mobility still leads to a proportionate increase in energy consumption. The amount of energy needed per unit growth must be reduced, while the development of energy carriers and technologies to ensure low-cost energy supply is of great importance. Development and sales of energy systems are also major components of wealth creation, from automobiles to complete power stations, creating substantial employment and export opportunities, especially to the industrialising nations. European leadership in hydrogen and fuel cells will play a key role in creating high-quality employment opportunities, from strategic R&D to production and craftsmen.

In the US and Japan, hydrogen and fuel cells are considered to be core technologies for the 21st century, important for economic prosperity. There is strong investment and industrial activity in the hydrogen and fuel cell arena in these countries, driving the transition to hydrogen – independently of Europe. If Europe wants to compete and become a leading world player, it must intensify its efforts and create a favourable business development environment.

Air quality and health improvements

Improved technology and post-combustion treatments for conventional technologies are continuously reducing pollutant emissions. Nevertheless, oxides of nitrogen and particulates remain a problem in certain areas, while the global trend towards urbanisation emphasises the need for clean energy solutions and improved public transport. Vehicles and stationary power generation fuelled by hydrogen are zero emission devices at the point of use, with consequential local air quality benefits.

Greenhouse gas reduction

Hydrogen can be produced from carbon-free or carbon-neutral energy sources or from fossil fuels with CO_2 capture and storage (sequestration). Thus, the use of hydrogen could eventually eliminate greenhouse gas emissions from the energy sector. Fuel cells provide efficient and clean electricity generation from a range of fuels. They can also be sited close to the point of end-use, allowing exploitation of the heat generated in the process.

The table I illustrates how, in a mature hydrogen oriented economy, the introduction of zero carbon hydrogen fuelled vehicles could reduce the average greenhouse gas emissions from the European passenger car fleet, compared to the average level of 140g/km CO_2[(1)] projected for 2008.

Tabla I

Year	% of new car [(1)] fuelled by Zero-Carbon hidrogen	% of fleet fuelled by cero-carbon hidrogen	Average CO_2 reduction (all cars)[(2)]	CO_2 avoided per year (Mt CO_2)
2020	5	2	2,8g/km	15
2030	25	15	21,0 g/km	112
2040	35	32	44,8g/km	240

1) Figures based on an assumed Europen fleet of 175 Millions vehicles the fleet size will increase significantly by 2040, with correspondingly larger benefits.

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(1) The European Automobile Manufacturers' Association (ACEA) has made a voluntary commitment to reduce the average level of CO2 emissions to 140 g/km for new vehicles sold on the European market in 2008. The average level today is around 165-170 g/km.

2) Calculation is independent of total number of cars. The last column shows the corresponding amounts of CO_2 emissions that could be avoided. This may be compared to a projected total level of 750-800 $MtCO_2$ emissions for road transport in 2010. The numbers for H_2-fuelled cars are an assumption based on a survey of experts for conventional and alternative automotive drive trains, but not a prediction of future production or sales.

Greenhouse gas savings of about 140 $MtCO_2$ per year (14% of today's levels of CO_2 emissions from electricity generation) could be achieved if about 17% of the total electricity demand, currently being supplied from centralised power stations, is

replaced by more efficient decentralised power stations, incorporating stationary high-temperature fuel-cell systems fuelled by natural gas. Fuel-cell systems will be used as base load in the future decentralised energy systems.

These examples *are not proposed as targets,* but merely to serve as illustrations of the CO_2 savings that could be achieved with quite modest penetrations of hydrogen vehicles and fuel cell-based stationary power generation. Together, 15% regenerative hydrogen vehicles and the above distributed fuel cell/gas turbine hybrid systems could deliver about 250 $MtCO_2$ savings per year. This is approximately 6% of the energy-related CO_2 emissions forecast in 2030.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

To maintain economic prosperity and quality of life, Europe requires a sustainable energy system that meets the conflicting demands for increased supply and increased energy security, whilst maintaining cost–competitiveness, reducing climate change, and improving air quality.

Hydrogen and fuel cells are firmly established as strategic technologies to meet these objectives. They can create win-win situations for public and private stakeholders alike. The benefits will only start to really flow after public incentives and private effort is applied to stimulate and develop the main markets – stationary power and transport. This should be done in a balanced way that reflects the most cost-effective use of the various alternative primary energy sources and energy carriers.

Competition from North America and Pacific Rim countries is especially strong, and Europe must substantially increase its efforts and budgets to build and deploy a competitive hydrogen technology and fuel cell industry. This should not be left to develop in an uncoordinated fashion, at the level of individual Member States. Gaining global leadership will require a coherent European-level strategy, encompassing research and development, demonstration, and market entry similar to the development of the European aircraft industry.

The establishment of specific 'initiative' groups to take forward the development of a broad and far-reaching hydrogen and fuel cell programme, comprising:

Hydrogen production

Hydrogen can be produced in many different ways, using a wide range of technologies. Some of these involve established industrial processes while others are still at the laboratory stage.

Some can be introduced immediately to help develop a hydrogen energy supply system; while others need considerable research and development.

Current hydrogen production is mostly at a large scale. Before a hydrogen energy system is fully proven and fully introduced, many regional demonstration and pilot projects will be required.

Aside from large-scale industrial equipment, small-scale production technologies, including electrolysers and stationary and onboard reformers, which extract hydrogen from gaseous and liquid fuels like natural gas, gasoline and methanol, will be needed.

Many organisations are developing technologies specifically for this scale of operation. Safety will be a paramount issue. The table 1 below compares the principal hydrogen production routes.

Hydrogen storage

Hydrogen storage is common practice in industry, where it works safely and provides the service required. Also, hydrogen can easily be stored at large scale in vessels or in underground caverns. However, for mobile applications, to achieve a driving range comparable to modern diesel or gasoline vehicles, a breakthrough in on-board vehicle hydrogen storage technology is still required. Innovative vehicle designs could help overcome current drawbacks. Significant research and development is under way, with new systems in demonstration.

Conventional storage, such as compressed gas cylinders and liquid tanks, can be made stronger, lighter and cheaper. Novel methods, including hydrogen absorption using metal hydrides, chemical hydrides and carbon systems, require further development and evaluation.

Hydrogen end-use

Hydrogen can be burned either to provide heat, or to drive turbines, or in internal combustion engines for motive and electrical power. Many of these technologies are quite mature, although improvements in materials and processes will help them work better and last longer. Fuel cells are in the early stages of commercialisation and offer a more efficient hydrogen use. Hydrogen internal combustion engines in vehicles may provide an important route to enable hydrogen introduction while other technologies, such as fuel cell electric drive trains develop.

Hydrogen infrastructure

Infrastructure is required for hydrogen production, storage, and distribution and, in the case of transport, special facilities will be required for vehicle refuelling. This has implications for landuse planning as well as for the safe operation and maintenance of hydrogen equipment.

Other issues must also be addressed. Trained maintenance personnel, specifically trained researchers; accepted codes and standards all form part of a successful support infrastructure for any product or service, and will be vital for the successful introduction of hydrogen and fuel cells.

The use of hydrogen-fuelled transport will depend on the successful development of an affordable and widespread refuelling infrastructure. Currently, only a few expensive hydrogen refuelling stations exist worldwide, and refuelling station costs need to be reduced to make them commercially viable. The greatest challenge will be to support millions of private cars but, before that, fleet vehicle fuelling stations will be introduced. Providing hydrogen fuel for ferries and other local water-based vehicles could also come early in the development of an infrastructure, particularly in environmentally sensitive areas.

Relative greenhouse gas emissions and costs of hydrogen fuelling pathways

The total electricity generating capacity in the 15 European Union member states (EU15) is currently around 573GWel. Forecasts for 2020 to 2030 predict electricity generating capacities from fuel cells will be in the range 30 to 60 GWel.

Assuming fuel cell generating capacity of 60 GWel by 2020- 2030 (at the upper end of the forecast range), would result in CO_2 savings of around 140Mt per annum. This would correspond to around 10% of forecast CO_2 emissions in 2030 from electricity generation in the EU15. These figures assume base load operation of future natural gas fuelled fuel cell power stations having an efficiency of 60% and operating 7500hours per year, with no CO_2 capture.

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EL RETO DE LA ENERGÍA ....EL HIDROGENO

RERSUMEN

La energía constituye la savia de la sociedad y de la economías actuales. Nuestro trabajo, nuestro ocio y nuestro bienestar económico, social y físico dependen de que el abastecimiento de energía sea suficiente y no se interrumpa. Sin embargo, actuamos como si estuviera garantizado, y la demanda de energía continúa creciendo año tras año. Las fuentes de energía tradicionales basadas en combustibles fósiles tales como el petróleo son limitadas, y el creciente desfase entre una demanda en aumento y una oferta en retroceso tendrá que ser compensado, en un futuro no muy lejano, utilizando fuentes de energía primaria alternativas. Tenemos que esforzarnos por que éstas resulten más sostenibles y así conjurar los efectos negativos del cambio climático planetario, el riesgo creciente de perturbaciones del abastecimiento, la volatilidad de los precios y la contaminación de la atmósfera asociados a los sistemas energéticos actuales.

La política energética de la UE (1) aboga por garantizar la seguridad del abastecimiento de energía y reducir al mismo tiempo las emisiones asociadas con el cambio climático. Esto exige actuaciones inmediatas de fomento de las fuentes de energía que no generan emisiones de gases de efecto invernadero, tales como las renovables, de los combustibles alternativos para el transporte y del aumento de la eficiencia energética.

En este contexto, dos tecnologías están atrayendo la atención de las autoridades públicas y del sector privado:

el hidrógeno, vector energético limpio que puede producirse a partir de cualquier fuente de energía primaria, y las pilas de combustible, dispositivos muy eficientes de conversión de energía. El hidrógeno y las pilas de combustible, al hacer posible la denominada energía del hidrógeno, prometen como ninguna otra tecnología disipar nuestras inquietudes en materia de seguridad del abastecimiento y cambio climático.

El informe subraya la necesidad de efectuar una planificación estratégica y de redoblar los esfuerzos en materia de investigación, desarrollo y despliegue de las tecnologías del hidrógeno y de las pilas de combustible.

INTRODUCCIÓN

La demanda mundial de energía está creciendo a un ritmo alarmante. La «Perspectiva mundial sobre política climática y tecnología energética» WETO (This World Energy, Tecnology and Climate policy Outlook) europea predice para la energía primaria en el mundo un crecimiento medio del 1,8 % anual durante el período 2000-2030. Esta mayor demanda se satisface fundamentalmente utilizando las reservas de combustibles fósiles, que emiten gases de invernadero y otros contaminantes. Reservas que, por otra parte, irán encareciéndose a medida que vayan disminuyendo. Actualmente, el nivel de emisiones de CO_2 per cápita en las naciones en desarrollo asciende al 20 % del correspondiente a las grandes naciones industriales. Esta proporción se incrementará sustancialmente al industrializarse los países en desarrollo. Para 2030, las emisiones de CO_2 de los países en desarrollo podrían representar más de la mitad de las emisiones mundiales de CO_2. Los países industrializados deberían liderar el desarrollo de nuevos sistemas energéticos que puedan contrarrestar esta tendencia.

El abastecimiento seguro de energía constituye un problema importante. Los combustibles fósiles, en particular el petróleo, se produce solo en determinadas zonas del mundo, por lo que la continuidad del abastecimiento se ve gobernada por factores políticos, económicos y ecológicos. Estos factores conspiran para que los precios del combustible resulten volátiles, y a menudo elevados, al tiempo que la política de medio ambiente exige una reducción de los gases de invernadero y de las emisiones tóxicas.

Resulta necesaria una estrategia energética coherente, referida tanto a la oferta como a la demanda, que tenga en cuenta el ciclo de vida completo de la energía, incluyendo la producción, transmisión y distribución del combustible y la conversión energética, así como el impacto sobre los fabricantes de equipos energéticos y los usuarios finales de los sistemas de energía. A corto plazo, el objetivo debería ser aumentar la eficiencia energética e incrementar el abastecimiento basado en fuentes europeas, en particular renovables. A largo plazo, una economía basada en el hidrógeno tendrá consecuencias para todos estos sectores. A la vista de los avances de la tecnología, los fabricantes de vehículos y componentes, los transportistas, la industria de la energía e incluso los particulares están pensando seriamente en adoptar combustibles y fuentes de energía alternativas y en tecnologías más eficientes y limpias, en particular el hidrógeno y las pilas de combustible alimentadas por hidrógeno.

En el presente trabajo, se subraya el potencial de los sistemas energéticos basados en el hidrógeno a nivel mundial, y en particular en Europa, en el contexto de una estrategia general en materia de energía y medio ambiente. A continuación, señala las estructuras y actividades de investigación necesarias para su desarrollo y su despliegue en el mercado.

METODOLOGÍA

La metodología utilizada en el presente trabajo ha consistido en la consulta de diversas bibliografías, para poder entender correctamente la evolución del tema tratado.

Se ha utilizado además de la bibliografía ordinaria la información disponible en la red en portales de organismo internacionales solventes. La bibliografía ha sido tanto nacional como internacional.

Finalmente complementamos el artículo con la información más reciente en cuanto a la legislación correspondiente a dicho tema por parte del organismo correspondiente de la UE. Asociación Europea del Hidrogeno. HyWeb – the Hydrogen and Fuel Cell Information.

Posteriormente el análisis del material recopilado, el examen y comprensión de los contenidos tanto en el tiempo como en el espacio, configurarían el estudio del contexto. Como en toda revisión, la documentación consultada es el sostén de nuestras opiniones sobre el tema propuesto, llegando finalmente a las conclusiones que culminan este trabajo.

CONCLUSIONES

Para preservar la prosperidad económica y la calidad de vida se necesita un sistema de energía sostenible capaz de hacer frente a las demandas contradictorias de aumento del suministro, mayor seguridad, mantenimiento de la competitividad de costes, lucha contra el cambio climático y mejora de la calidad del aire.

El hidrógeno y las pilas de combustible están sólidamente asentados como tecnologías estratégicas para alcanzar estos objetivos, y pueden crear situaciones en las que tanto las partes interesadas públicas como privadas salgan ganando. Los beneficios sólo empezarán a hacerse patentes si se aplican incentivos públicos y esfuerzos privados al fomento y al desarrollo de los mercados principales: producción energía estacionaria y transporte. Y esto debe hacerse de forma equilibrada, reflejando el uso más eficaz en función de los costes de las diferentes fuentes de energía primaria y vectores energéticos alternativos.

La competencia de los países de América del Norte y del arco del Pacífico es especialmente vigorosa, y es imprescindible que Europa incremente sustancialmente sus esfuerzos y sus presupuestos para construir y desplegar una industria de pilas de combustible y una tecnología del hidrógeno competitiva. Y no debe permitirse que esto suceda de forma descoordinada, a nivel de cada Estado miembro.

Para ser líderes en el mundo será necesaria una estrategia coherente a nivel europeo que incluya la investigación y el desarrollo, la demostración y la entrada en el mercado, en la línea seguida para el desarrollo de la industria aeronáutica europea.

Por consiguiente, es necesario crear unos «grupos de iniciativa» específicos capaces de impulsar el desarrollo de un programa amplio y ambicioso en materia de:

Producción de hidrógeno

El hidrógeno puede producirse por vías muy distintas, utilizando una amplia gama de tecnologías. En algunas de ellas intervienen procesos industriales consolidados, mientras que otras están aún en fase de laboratorio. Algunas se podrían introducir inmediatamente para contribuir al desarrollo de un sistema de abastecimiento de energía a partir del hidrógeno, mientras que otras precisan todavía de una investigación y desarrollo considerables.

Actualmente el hidrógeno se produce principalmente a gran escala. Para tener un sistema energético basado en el hidrógeno plenamente comprobado y totalmente introducido serán necesarios numerosos proyectos piloto y de demostración regionales. Aparte de los equipos industriales a gran escala, resultarán necesarias tecnologías de producción a pequeña escala, incluidos electrolizadores y reformadores o estacionarios y de a bordo, que extraen hidrógeno de combustibles líquidos y gaseosos tales como el gas natural, la gasolina y el metanol. Muchas organizaciones están desarrollando tecnologías específicamente para esta escala de funcionamiento. Siendo la seguridad una cuestión vital..

Uso final del hidrógeno

El hidrógeno puede utilizarse para generar calor por combustión, para impulsar turbinas o, en motores de combustión interna, para generar energía eléctrica y de movimiento. Muchas de estas tecnologías están ya maduras, aunque la mejora de los materiales y los procesos contribuirá a que funcionen mejor y duren más. Las pilas de combustible se encuentran en sus primeras fases de comercialización y ofrecen mayor eficiencia en el uso del hidrógeno. Los motores de combustión interna de hidrógeno instalados en vehículos pueden constituir un buen medio de introducción del hidrógeno, en tanto se desarrollan otras tecnologías, tales como grupos motopropulsores eléctricos de pilas de combustible.

Infraestructura del hidrógeno

Es necesaria cierta infraestructura para la producción, el almacenamiento y la distribución del hidrógeno, y en el caso del transporte harán falta unas instalaciones especiales para que los vehículos reposten. Esto tiene consecuencias para la planificación del uso del suelo, así como para la explotación y el mantenimiento seguros de los equipos relacionados con el hidrógeno.

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SHORT SEA SHIPPING OPPORTUNITIES FOR THE PYRENEAN CARGO FLOWS

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ABSTRACT

This paper tries to show the results and conclusions reached by a small research team within the TRANSMAR research group of the Nautical Engineering and Sciences department from the Technical University of Catalonia, the research study carried out has been called INECEU (Intermodality between Spain and Europe) and it has been endorsed by the Spanish Ministry of Transport. The main objective of this study was to evaluate the chances for the maritime transport within a multimodal chain, to alleviate the freight road traffic crossing every year the Pyrenean border. In fact, there is well known the limitations of the terrestrial infrastructures, being nowadays supporting a high degree of congestion. Thus the possibility to pass a part of those goods carried by truck to the maritime mode, would help to reduce those highways overloading, and also improving the pollutant particles and gases emissions. In a first instance the transport by sea, is the most efficient in consumption and pollution terms. However its own justification is not dependent only from the sea leg figures in a multimodal chain but from the overall steps by which the cargo loaded on board should pass.

Key words: Cargo flows, Sea trade, coastwise, intermodality, Pyrenees

INTRODUCTION

The European Commission and Member States appreciate that transport in Europe is growing at a high rate and that beyond 2010 it is possible the figures for inter European transport, including the new accession countries, will show a growth

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of over 80% in volume, and unfortunately these values will be absorbed mostly by road transport. Still around 45% of European Union foreign trade is still carried by road and is consequently conditioned by traffic congestion or high fuel consumption, implying disadvantages related to pollution and safety. Meanwhile up to 40% of the before mentioned volume is carried by short sea shipping. Short Sea Shipping in European waters has been considered by national and European governments as one of the most feasible ways to alleviate the congestion that gets worse every day on the roads and highways across Europe.

The European Union has gone one step further by approving an overall budget of 740 millions € over 7 years (from 2007 to 2013) for a programme that will include funding for TEN – T,[1] dedicated aspects of Galileo and Marco Polo programmes, for the development of means of transport other than road transport.

The geography.

From 1991 to 2000, transport volumes increased between the Iberian Peninsula and other EU states, having affected all the means of transport in the following percentages; 40% for road, 41% for shipping and up to 32% for rail, even though it decreased in general terms. The share of each means of transport favours road with 52%, shipping 43% and rail only 5%. In 1998 the volume of cargo haulage by train was only 4.7 millions of metric tonnes, and for combined transport (ferroutage) this amounted to 2.4 millions of metric tonnes, but up to 56.9 millions of metric tonnes by truck during the same year. When talking about light and specific vehicles the trends have shown an increase of up to 33% in 10 years among the two means. The previous figures translated to absolute numbers bring us up to 17,000 heavy vehicles passing the Pyrenean border in the year 2000 [2]. The permeability of this mountain range, has been discussed in different fora such as the *Comunidad de Trabajo de los Pirineos* [3], an organisation that represented both sides of this natural barrier whose main objectives were to identify as the main problem, the lack of enough transport networks, linking the Iberian peninsula and Europe.

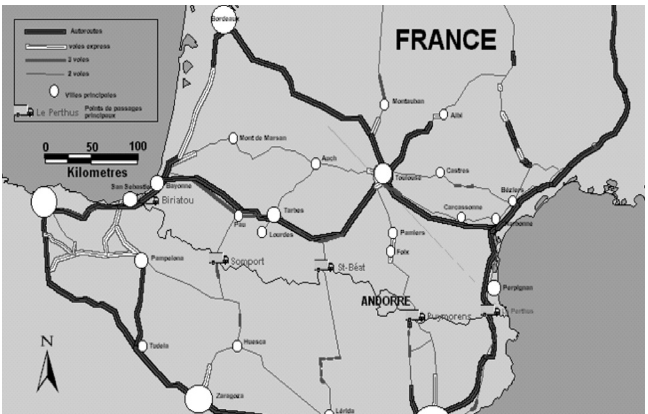

Figure 1. The Pyrenean border during the year 2002 and the communications network
Source: Conseil Regional Midi Pyrenées, year 2004.

Existing communication links.

The ways currently used for carrying goods from one side of the Pyrenean border to the other are mainly road accesses as follows:

1. Donostia-Irún (A-8) to Biriatou-Bayonne (A-63).
2. Iruña-Roncesvalles (N-135) to St. Jean Pied de Port-Ortez (D-933) (a highway is intended).
3. Iruña-Salies de Béarn or Transnavarra highway just opened.
4. Huesca Jaca-tunnel of Somport (N-330) to Oloron St Marie-Pau (N-134).
5. Ainsa tunnel of Bielsa (A-138) to Lannemezan (N-125)
6. Lleida-tunnel of Vielha (N-230) to Pont del Real-St. Béat (N-125) towards Toulouse.
7. Barcelona-Puigcerda (A-18, C-16, N-260) to Bourg Madame-Foix-Toulouse (N-20).
8. Barcelona-La Jonquera (A-7) to Le Boulou-Perpignan (A-9).

Although there seems to be plenty of choice, the volume is, in practice, concentrated in 90% travelling throught the two coastal highways (1 and 8) because of the higher quality roads.

Regarding the railway, the lines in service are mainly the two coastal passes and one minor central passage:

1. Donostia-Hendaya to Bayonne.
2. Ripoll to La Tour de Carol-Foix.
3. Figueres-Portbou to Perpignan and connection to Céret.

There is planned for the future the Canfranc Pyrenean passage (linking that city through a tunnel under the Somport with Oloron-Buzy in Béarn and Pau) that is in the region of Aragon and is being promoted to be considered as another choice. After the major work to be done, it will eventually be capable of dealing with up to 3 millions of tonnes per year.

However, studies carried out [4] are confirming that the origin of the problem of overloading rests on the next points:

1. The railway network crossing the Pyrenees is limited to the 2 coastal passes that were built 125 years ago.
2. The different rails width.
3. Blockage at the frontier due to road congestion.
4. The increase of the flow of goods crossing the border. In 1998 up to 14,000 trucks per day and this rate is on the increase, being 17,000 in 2002, and 19,300 in 2005.

The capacity of land carriage is complimented by air traffic with a minor impact in terms of volume, and also the shipping link from commercial ports in Spain with others in Europe.

INTRA EUROPEAN COASTAL TRANSPORT

If a European coastal trade may be defined as that carried out within the European geographical limits and even reaching the sea areas near to the European coasts, it should include the short sea trade. Taking a quick look into the last technical advances in the marine sector, we identify three basic pillars on which modern shipping rests; bulk, container and rolling cargoes. All of them are so specific that they have particular features regarding their logistic chains and performances [5]. We should consider bulk transportation of mass freight where the ship is the most favourable option compared to the truck. However, when we consider the container and Ro/Ro services available we can see that for regular traffic there are opportunities for a steady flow of cargo for road to sea and vice versa. There is a future to be considered when talking about container traffic because the trend of reducing port calls for the larger container carriers entering each year into a few hub ports, should be backed by frequent feeder services that are spread out and that should be included in the short sea shipping European trade. Ro/Ro services have also been firmly placed as a link between insular territories and the mainlands as communications links within closed seas and generally on the basis of a fast transhipment of cargo loaded on trucks, trailers or specific platforms. There are true cabotage and short sea trades, not only in Europe as the paradigmatic case of Grimaldi Napoli, but in our country mainly Grupo Boluda with Naviera Pinillos, Vapores Suardíaz or Contenemar. However a brief look will confirm the real chances that short sea services have in Europe, provided the future funding and regulations are approved for their endorsement. Superfast ferries are Greek owned, previously serving in the Adriatic and Baltic seas and they recently opened a service between Zeebrugge and Rosyth in Scotland, therefore avoiding the long trip for trucks from the North of Great Britain.

Grimaldi Napoli, have consolidated its Barcelona-Genoa line and a few months ago introduced the Barcelona-Civitavecchia and Valencia-Civitavecchia services, with successful results. Brittany Ferries and P&O ferries have provided services in the English Channel for a long time now and it has reinforced its services between Spain and Great Britain. The *Pont Aven* is the latest ferry presented last October by Brittany Ferries. Naviera Pinillos from Group Boluda, using container and Ro/Ro ships, is serving Canary Islands traffic with the mainland but also maintains services from the peninsula and islands to Italy, Great Britain or Mauritania. Also Contenemar, serves certain container traffic, not only with Spanish archipelagos but also with the Atlantic coast of Africa, Livorno, Civitavecchia or Southampton, Flushing and Zeebrugge together with ports in the eastern Mediterranean. Cobelfret's Belgian owner, have most of their ships flagged in Luxemburg and is a solid provider of traffic between mainland ports and the UK, but it is an example of a transport provider for the Swedish paper manufacturer Stora-Enso. And last but not least we ought to note the Spanish owner Group Suardiaz providing service with 16 car carriers, 13 ships being involved in regular lines to Flushing, Zeebrugge, Southampton, Italy or eastern Mediterranean. The last service opened in November is Flushing-Zeebrugge-Santander-Bilbao. There are examples of fixed contracts such as the one signed with the NATO for serving in any required traffic in Europe, or the GEFCO (Peugeot-Citroen) contract linking Vigo with Saint Nazaire and Toulon, that is being served by Trasmediterranea.

THE EUROPEAN TRANSPORT NETWORKS

The European Commission has promoted a set of measures directed to coordinate and unify European transport objectives, avoiding the different legislation distortions that would have a negative influence on and increase the price of cargo and passengers transport. We could look at October 1992 when the Maritime Industries Forum recommended the: "*promotion of the short distance and multi modal maritime transport, facing the problems in the use of the maritime transport as a challenge to oppose road transport*".

In 1994, the Essen European Council, adopted 11 of 14 priority projects regarding transport resources and in 1996, the European Parliament and Council, drew up the future guidelines for the trans European transport networks towards the year 2010. In 2001, the decision was revised in order to admit maritime and inner ports into the transport policy. In fact the Trans European Transport Network or TEN is a concept formulated in some of the above mentioned European documents that originated in the Maastricht Treaty, which requires the Community to contribute to the creation and development of such transport and communication networks. Further in September of 2001 and triggered as a response to the Mont Blanc accident of 1999, the European Commission presented the "*The European transport policy towards 2010: time to decide*" White Paper, that posed among its priorities, to look for an alternative to the congested road passages and mainly those of the Alps and the Pyrenees. The coastal services are initially very difficult to be started up and being conscious of this, the EC proposed to identify and help them through initiatives such as the Marco Polo and previously the PACT structural funds, focusing on the establishment o the new short trade shipping lines. During the month of June 2002 in Gijón, the EU Transports Ministers informal meeting was held, where it was decided to draft a plan for promoting coastal shipping transport. That concluded in the 14 points programme for stimulating short sea trade, with the sea highways concept being among them once again. Some of the first reactions to the Gijón declaration were two French Parliamentary reports called François Liberti in 2002 and Henri de Richemont [6] in 2003. This last report proposed policies to promote Ro/Ro services in French ports, which are justifiable although there are a lack of key items (capitalisation, inadequate offer or absence of industrial dedicated traffic) that are expected to be facilitated by the local authorities.

The van Miert Group, led by the ex EC transport commissioner Mr. Karel van Miert, carried out a study of over 100 proposed projects [7] by the member states, in order to select the most urgent ones and to distribute available funds. This study kept in mind factors such as the technical and finacial ones, together with their agreement to European transport policies as proposed in the white paper, funding possibilities, together with the real chances to be carried out. 22 priority projects were chosen including the sea highways and the 5 projects known as Essen [8], close to their finalisation. Those projects should be started before the year 2010, whilst the European Commission carries out a detailed impact study and proposes a revision of the community guidelines for the development of transport networks [9]. The van Miert report was further developed when the European Parliament Transport Committee passed, on 17 February 2004, the preliminary report by Philip Bradbourn on the Communitarian directives for TEN-T development. The European Commission confirmed the decision in March keeping in mind that this should be a tool for improving the articulation of the 25 members Europe and also providing for the development of the sea highways, simplifying frontier procedures and ensuring that such highways are free of bottlenecks and really are promoting alternatives such as sea transport for the regular bulk trades. The case of Spain is a good example as it is a peripheral country that would suffer to a greater extent any lack of infrastructures. The term "sea highways" are defined in the van Miert report presented in Brussels, establishing up to four:

1. Baltic (link between Baltic and central-north European states).
2. Atlantic (link between the Iberian peninsula, Ireland and the North Sea).

Source: Rete Autostrade Mediterranee SpA, year 2004.

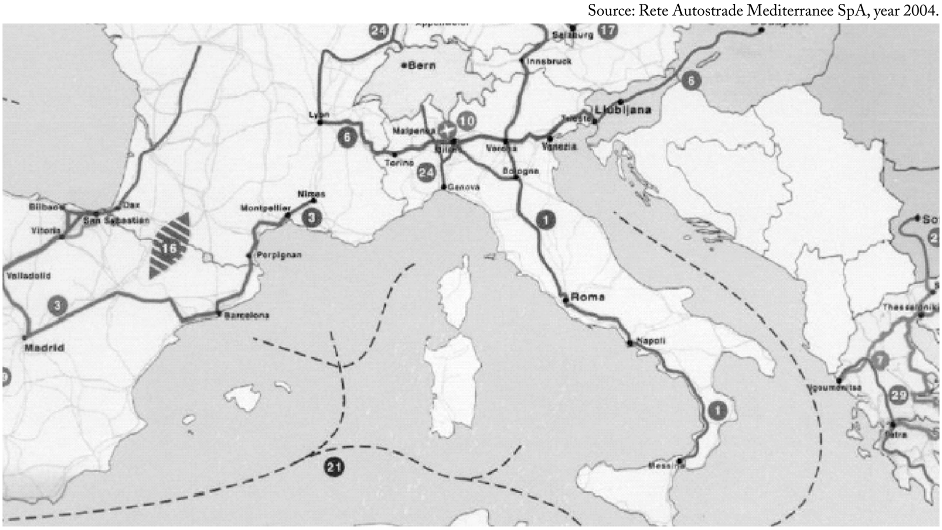

Figure 2: Map showing some of the van Miert report selected projects.

3. West Mediterranean (link between the Adriatic sea with the Ionian sea reaching Cyprus).

4. East Mediterranean (link between Spain, France, Italy and Malta connecting with the Atlantic highway).

The sea highways intend to improve connection with the insular countries and those that are isolated because of the natural separation of the Alps or Pyrenees or the Baltic Sea.

METHODOLOGY OF STUDY.

The present study was divided into three main phases. The first one was focused on an analysis of existing projects and studies closely related to the same topic, available bibliography and gross data sources. A second phase intended to propose different sea corridors, depending on the cargo fluxes and volumes or the production and consumption centres in Spain. The points to be used as connections for moving the cargo were, of course, the ports along the Spanish coast, connected by two of the seaways previously mentioned. On a first analysis, the cargo to be transferred from road to sea would be mainly iron and chemical products, food stuff in general but mainly agricultural produce, largely concentrated in Andalusia and Levante coasts. This last would be easily packed in container units that facilitate intermodality. Once the chances for transferring the cargo to shipping had been evaluated, the high speed use was studied for certain kinds of perishable goods. The last and final step covered the criteria and recommendations arising from the previous two and studied the best port facilities that would provide safe and quick cargo transfer. The difficulties of those ports for connection to the main communications axes with the hinterland, the need for new open traffic corridors in certain ports or the railway links, need to demonstrate they are a viable alternative to the truck.

Looking deeper into this, when the study had just started, some quite interesting European projects were identified, such as INSPIRE, SSS CA, EMMA [11] or even the most recent REALISE [12] inter alia, very close to the sea trade question of our study together with some others funded by SPC-Spain. [13]. Further, the viability analysis of the routes, was initiated using the figures provided by a permanent enquiry for trucks carried out by the French and Spanish governments in the Pyrenees.

The following table shows the cargo volumes moved over the Spanish borders during 2003, using data from the governmental enquiry already mentioned.

The total exchanged volumes were also classed by type of cargo and their origin or destination in Spain. So the parameters to be studied were:

1. Total volumes in export and import flows by truck, segregated by country.
2. Total volumes exchanged by truck, classed by groups of commodities.

Source Spanish Ministry of Transport, year 2004

Cargo moved by road	Imports (Tm.)	Exports (Tm.)	TOTAL (Tm.)
FRANCE	10,839.000	10,069.000	20,908.000
GERMANY	3,250.000	3,395.000	6,645.000
HOLLAND	866.000	908.000	1,774.000
UNITED KINGDOM	698.000	1,529.000	2,227.000
BELGIUM	1,020.000	681.000	1,701.000
ITALY	2,280.000	2,352.000	4,632.000
PORTUGAL	2,423.000	3,816.000	6,239.000
OTHERS EU-15	102.000	143.000	245.000
TOTAL EU-15	21,480.000	22,893.000	44,374.000

Table 1: Cargo volumes moved over the Spanish borders.

3. Spain was divided into 5 different areas, representing each one homogeneous production and consumption zones and selecting some transport centres or logistic platforms.[14].

Some ports were selected in Spain depending on the kind of cargo mostly moved and the distance to the closest transport centres.

DEVELOPMENT AND PRELIMINARY RESULTS.

Once the largest exchange volumes were identified, the research group centred on these. Those countries were France, Germany and Italy.

Regarding the groups of selected goods:

1. Agricultural products and live animals.
2. Foodstuffs and animal fodder (alcohol drinks and tobacco).
3. Ores, metal waste and products.
4. Chemicals.

The two first would be very easily packed in unitized cells or cargo units, easing their inclusion in multimodal chains and a quick and efficient passage between different transport modes. We should clarify that the volumes and types of cargo are not coincident with the overall figures between Spain and Europe, but with the road exchanges. In the first case the largest party would of course be oil products, machinery, manufactured goods and transport equipment.

Segregated by geographical areas, the production of agricultural products for exportation purposes come mainly from Andalusia and Valencia regions using

Valencia, Alicante, Cartagena, Almería or Huelva ports. Using distance criteria, we should remember that, for example, metal ore and its related manufactured goods, may be imported to the peninsula through specialised ports along the Cantabrian coast such as Gijón, Bilbao, Pasajes or Santander, and following the same criteria the chemical and oil products would be shipped close to refineries.

At the same time there are some ports specializing in certain export traffic as follows:

Containerized traffics:

1. Fruits, vegetables and beans: Algeciras, Barcelone, Cartagena, Valencia and Castellon.
2. Wine and alcohol drinks: Valencia, Barcelone, Algeciras and Bilbao.
3. Canned food: Algeciras, Valencia, Cádiz, Cartagena and Bilbao.

Bulk traffic:

1. Cereals and flour: Cadiz, Seville and Valencia.
2. Iron ore: Huelva and Seville.
3. Steel manufactures: Bilbao, Pasajes, Valencia and Gijon.
4. Chemicals: Barcelona., Algeciras, Tarragona, Huelva, Valencia and Ferrol.

The main import flows are conducted through:

Bulk traffic:

1. Iron ore: Gijón (the largest), Pasajes, Bilbao and Santander.
2. Iron scrap: Pasajes, Bilbao, Algeciras, Ferrol, Sevilla and Santander.
3. Steel products: Valencia, Bilbao, Barcelona, Seville, Pasajes, Algeciras and Coruña.
4. Chemicals: Barcelona, Tarragona, Valencia, Algeciras, Huelva and Bilbao.

Once the main data was obtained, a forecast exercise was done in order to confirm the future justification of the proposed sea lines. It was estimated that during the year 2005, around 51 millions of tonnes would be moved by road, being the 75% between Spain and France, Italy and Germany. Also the expected figures for the year 2010 could reach the 74 millions of tonnes.

The national centre for the promotion of short sea ship-

Source, own research results.

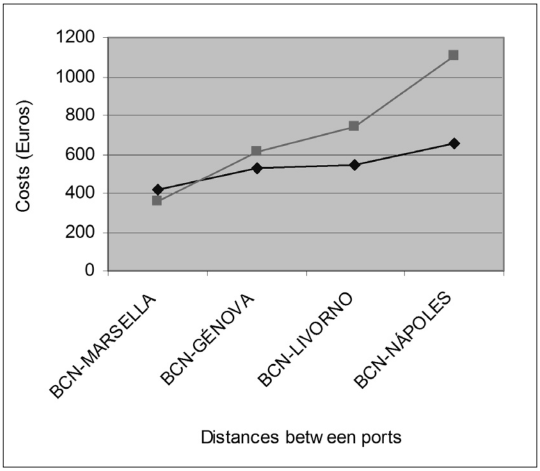

Figure 3: Curves showing the cost tendencies suffered by a unimodal chain (pink) carried by truck and the same one through a multimodal chain (blue).

ping (SPC-Spain) is convinced that certain conditions must be met for the success of maritime transport as:

1. A minimum distance of 450 nautical miles.
2. In order to absorb road traffic, a minimum road distance of 1.500 kilometres would be necessary.
3. The need for increasing ship speed for maximising the number of rotations.
4. To maximise shipping services for providing the quickest service to the ship in port.

In brief, we propose more efficient multimodal chains in terms of time and cost, capable of competing with road haulage. Calculations were made taking actual costs for road transport and an average speed of 75 kilometres per hour at a fixed cost of 28,11 € per hour together with a variable cost of 0,337 € per kilometre, considering tolls. The ship's costs were calculated based on the average prices paid by a 25 tonnes truck adding the port costs and an additional cost representing the operational charges. These figures were combined in order to get time and costs comparisons between the road trip compared with a multimodal chain cost, keeping in mind the ship's cost and voyage time added to the outer legs covered by truck. The results showed in the Mediterranean basin, linking the Seville manufacturing area through its port unloading in Marseilles to reach Lyon, that the multimodal chain would be more efficient than the truck, and even linking the first with Milan unloading in Genoa.

Source, own research results

Origin	**Transport mode**	**Loading port**	**Discharge port**	**Destination**	**Total time**	**Total cost**
Seville	Ship	Cadiz	Marseilles	Lyon	**2d 1,9 h**	**1103,5 €**
		Huelva	Marseilles	Lyon	**2d 4,6 h**	**1121,4 €**
		Seville	Marseilles	Lyon	**2d 3,75h**	**1056,2 €**
Seville	Truck	-	-	Lyon	**2d 5,2 h**	**1237,1 €**

Table 2: Comparison of time and cost figures between road and multimodal chains, from Seville to Lyon.

.Another efficient multimodal chain would be to link the Zaragoza manufacturing area through Tarragona port unloading in Genoa to reach Milan rather than the truck.

In the Atlantic, one chain is that linking Germany with the centre of the peninsula and it is an excellent example of a cheaper and more efficient chain.

Source, own research results

Origin	Transport mode	Loading Port	Discharge port	Destination	Total time	Total Cost
Luceni (Zaragoza)	Ship	Tarragona	Genoa	Milan	**1d 5,5 h**	**848,1 €**
Luceni (Zaragoza)	Truck	-	-	Milan	**1d 8,4 h**	**928,5 €**

Table 3: Comparison of time and cost figures between road and multimodal chains, from Luceni to Milan.

Source, own research results

Origin	Transport mode	Loading port	Discharge port	Destination	Total time	Total cost
Madrid	Ship	Bilbao	Hamburg	Berlin	**2d 20,4h**	**1464,7€**
		Santander	Hamburg	Berlin	**2d 18,7h**	**1436,2€**
Madrid	Truck	-	-	Berlin	**3d 5,2 h**	**1719,7€**

Table 4: Comparison of time and cost figures between road and multimodal chains, from Madrid to Berlin

CONCLUSIONS.

This paper shows the results of the INECEU project, proposing after an exhaustive study alternative multimodal lines as against road transport. There are of course administrative and documentary problems within ports, but we are sure that these will be solved in a near future. Keeping in mind the figures of road traffic passing the Pyrenean borders, we analysed most of the volume moved between Spain and France. Among all the Spanish regions we should note the activity of Catalonia, the Basque country, Valencia and Andalusia. The French counterpart is contested by the Pyrenean regions of Aquitaine, Languedoc-Roussillon and Midy-Pyrenees together with Ile-de-France, Rhône-Alps and Provence-Alps-Côte d'Azur. The French territory is also crossed by important traffic fluxes southbound coming from Westafalia, Baden-Würtemberg and Bayern in Germany and the northern part of Italy. From Spain it is possible to identify the main traffic towards Westfalia and Baden-Würtemberg in Germany, Lombardia in Italy and destinations more spread out up in Great Britain, Holland and Belgium. Regarding the nature of the cargo, we should note that the South and South-East part of the Iberian peninsula, together with the Valencia coast; are big producers of fruits and vegetables, with the group of manufactured or canned food and alcoholic drinks being one of the larger cargo groups that is exported from Spain. There is important traffic involving solid bulk such as building materials or scrap iron, together with oil and chemical products from ports with refineries nearby that are firmly committed to removing trucks carrying dangerous or toxic substances from the road to ships that have specifically designed containers, or Ro/Ros, that will benefit society as a whole.

We can conclude that:

1. There is a clear chance for short sea shipping provided minimum distances are respected, and then a cost advantage is seen, but there is no enough justification for the cargo to be passed from road to sea.

2. The bulk traffic should take advantage of the SSS funding and official policy using multi purpose ships for accepting different kinds of traffic.

3. Fast ships in this kind of traffic could be justified when serving trips less than 12 hours away and when cost is not so important provided a minor time of delivery can be guaranteed.

4. However the time spent in each modal shift should be considered and reduced to a minimum. It is possible to consider "time windows" for ensuring the cargo delivery on time.

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OPORTUNIDADES DEL SHORT SEA SHIPPING EN LOS FLUJOS DE CARGA TRANS PIRENÁICOS

Resumen

El presente artículo pretende divulgar, los resultados finales a los que ha llegado el proyecto INECEU (Intermodalidad entre España y Europa), llevado a cabo por un equipo de investigadores del Grupo TRANSMAR, del Departamento de Ciencias e Ingeniería. Náuticas en la Universidad Politécnica de Cataluña. La Subsecretaría de Transportes del Ministerio de Fomento ha sido la parte financiadora e impulsora del mismo, dada la importancia económica y social de los intercambios comerciales para la economía española con la Unión Europea y debido también a la sensibilidad y voluntad política, de promocionar el transporte marítimo de corta distancia y cabotaje por parte de la propia Comisión Europea.

El objetivo principal del proyecto INECEU se centra en la justificación de la viabilidad de líneas alternativas de transporte marítimo de corta distancia que puedan retirar parte de las mercancías que son intercambiadas por carretera entre España y Europa a través de los pasos Pirenaicos. El estudio parte del análisis de la situación actual del transporte por carretera mediante la evaluación sistemática de volúmenes de carga, destinos, orígenes y naturaleza de la misma, partiendo de las valiosas estadísticas proporcionadas por la encuesta permanente de transporte de mercancías por carretera, llevada a cabo por la Dirección General de Programación Económica del Ministerio de Fomento.

Ello presupone que las cifras de carga transportadas en tren, se respetarían y sólo se propondrían opciones viables en tiempo de tránsito y coste a los trayectos realizados en camión. Para contemplar una cadena multimodal de transporte rápida y eficiente, se supone que la mercancía se envasa en unidades de carga (contenedor, remolque de camión o Roll-trailer), que minimiza los costes derivados de la ruptura del medio de transporte. Al final del estudio se han propuesto unas opciones marítimas que de adoptarse en el contexto actual, permitirían la descongestión de las carreteras fronterizas con Francia e incluso se realiza un breve repaso a la posibilidad de utilizar buques de alta velocidad, para reducir en tiempo el tramo puramente marítimo.

El planteamiento general del proyecto INECEU, se desdobla en una serie de objetivos parciales, que revisan un conjunto limitado de aspectos a considerar como estudios previos existentes tanto de ámbito nacional como europeo. La identificación de los flujos de carga entre España y la UE mencionados, la identificación de los puntos de salida de la mercancía Española destinada a la exportación, y a su vez los puntos de entrada de la misma, que se encuentran estratégicamente situados, en términos de distancia, vías de comunicación o la pertenencia a un área de influencia portuaria; y que puedan también en función de las infraestructuras existentes, ser transportadas en medios unitizados.

El establecimiento de un sistema de cálculo de los costes y tiempo de tránsito tanto del transporte terrestre como del marítimo, a partir de la información proporcionada por el Observatori de costos del transport per carretera de la Generalitat de Catalunya y el análisis de las infraestructuras portuarias (grúas, rampas Ro/Ro, etc.), que puedan permitir a un puerto ser elegido como mejor opción, frente a otros puertos que quizás estén mejor situados en términos de distancia a su hinterland o menores costes de operación.

El proceso de análisis de viabilidad de las rutas, se inició con el estudio de las cifras de transporte por carretera con el resto de Europa. Las variables consideradas en este caso fueron:

— Volúmenes totales de exportación e importación por carretera, segregados por país.
— Volúmenes totales intercambiados por carretera, por grupos de mercancías.
— Se dividió la España peninsular en 5 zonas, seleccionando en cada una de ellas varios centros de transporte o plataformas logísticas que representaran un foco de producción y consumo.
— Se seleccionaron los puertos más próximos a los centros elegidos, que optimizaran el tramo terrestre hasta el puerto, en la parte Española.

Una vez establecidos los parámetros de análisis, éstos se consideraron eliminatorios en aras de simplificar el estudio. De modo que en el caso de los volúmenes totales por país, se tomaron los que mayor cantidad de intercambios llevaban a cabo, como los casos de Francia, Alemania, Italia, Reino Unido (no contemplada a propósito por su naturaleza insular), Holanda (a distancia considerable junto con Bélgica).

Entre los grupos de mercancías susceptibles de ser captadas por el tráfico marítimo por orden de importancia, encontramos los productos del reino vegetal, los productos industriales: alimentos, bebidas y tabaco, los metales y sus manufacturas y los productos químicos y derivados.

Segregados por zonas de producción, los productos agrícolas destinados a la exportación se concentran en las provincias de Levante y Andalucía, pudiendo expedirse por puertos como Valencia, Alicante, Cartagena, Almería, Sevilla o Huelva. Tomando un criterio de proximidad, los minerales metálicos y sus manufacturas entrarían en la península en las proximidades de los altos hornos como Gijón, Bilbao, Pasajes o Santander principalmente y los productos petroquímicos en las proximidades de las refinerías.

A la vista de los resultados obtenidos, emitimos unos criterios globales que se resumirían en los siguientes:

— Existen unas distancias mínimas que permiten la rentabilidad de la operativa del shorts sea shipping, pero el ahorro subsiguiente no motiva claramente el trasvase de carga del modo terrestre al marítimo.

— Los tráficos existentes de graneles, deberían tomar ventaja de las condiciones políticas de promoción del SSS pudiendo participar en el llenando buques multipropósito con retornos (en parte) de mercancía general.
— La alta velocidad en este tipo de transporte es justificable en distancias que supongan trayectos menores a 12 horas y en mercancías donde el tiempo de entrega pueda primar sobre el coste.
— El tiempo consumido en el cambio de modo de transporte debe de reducirse al mínimo posible y no obstante considerar unos “intervalos de tiempo” que permitan asegurar al receptor de la mercancía una horquilla de tiempo de entrega, razonable.

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HIGH SPEED CRAFTS IN THE CANARY ISLANDS

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ABSTRACT

For the Canary Islands, the sea is a path of obligatory use and on whose dependence the economic development of the inhabitants of the Archipelago, has been based. The problems of inter-insular maritime transport has been, and continues to be, a constant and growing worry up to the present moment, given the almost zero cargo capacity of the aeroplanes that render their services in the islands.

The boats that connect the islands have changed throughout the years, and these changes have been conditioned, in great part, by the special circumstances surrounding navigation in our waters: islands situated in open sea, exposed to all types of weather; particular meteorological conditions; swell; port infrastructures, etc. These circumstances have made the islands be a true bank of trials for the main types of HSC: hydrofoils, air cushion vehicles, high-speed mono-hull crafts, SES, jet-foils and catamarans, all which have navigated and run different luck. Today, there are three companies operating high speed crafts in the islands: Fred Olsen with five big catamarans, Trasmediterránea with two jet-foils and Garajonay Express with two smaller catamarans.

Key words: HSC, Marine Navigation, Navigation Evolution.

INTRODUCTION

The maritime mentality attributed to the inhabitants of the Canary Islands, based on geographic factors and their great dependency on the transport of mer-

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chandise by sea, is not sufficiently developed to allow the exploitation of the possibilities offered by the technology of high speed crafts, as has happened for decades in the neighbouring countries of continental Europe.

Up until a few years ago, the main economic activity of the Archipelago was agriculture, directed both for internal consumption and for its commercialisation in the rest of Spain, primarily bananas, tobacco, tomatoes, wine, tropical fruits, etc. This situation, though, has now changed and 74,6% of the regional richness is produced in the tertiary sector, fundamentally by tourism or activities linked to it.

In the last eighty years, the inter-insular connections have been preferentially maritime in regards to merchandise, and by air in regards to passengers, due to the fact that the cargo capacity of the aeroplanes that fly in the Canaries is of very scarce incidence. The company Bintercanarias, which covers practically the totality of passenger traffic between islands, transported in 2003 a total of 2.243,387 passengers (Bintercanarias, 2004). With the incorporation of the HSC, the incidence of maritime transport has considerably increased, being essential for the economy of the Archipelago, since almost all of the merchandise imported or exported, do so by means of cargo boats, mooring in the main harbours.

The Canaries have proved to be a true bank of trials for the HSC in open sea navigation. There are a total of seven principal islands and various small islands, divided in two provinces, with an extension that varies between the 1,928 km² of the island of Tenerife and the 227 km² of El Hierro. The Canarian population ascends to a total of 1.894.868 inhabitants, of which 915,262 live in the western islands, while 979,606 live in the eastern ones (INE, 2004). The meteorology is characterised by the trade winds, normal regime, which can be completed with the incidences of different Atlantic weathers: winter monsoons, invasions of maritime polar air, Atlantic storms and tropical depressions. These can affect the Canarian littoral causing a strong swell, in occasions with waves of up to 8 and 10 metres high, and causing the suspension of maritime navigation, although the normal height is of 2 metres. The islands also suffer, occasionally, storms from the West and East that cause substantial material damage in the harbour infrastructures.

The sea is, unquestionably, a useful and economic communication route between the islands, but the individual conditionings appertaining to each Community and the risen awareness of its value as a source of richness, have been interpreted and taken advantage of in very different ways. Within this diagnostic, especially relevant is how the HSC cope with the economic circumstances of maritime traffic. On the one hand lie the excessive cost of the modern units and the high expenses of the harbour infrastructures, while on the other, the consumption and price of fuel, which becomes more and more important. The latter is linked to the absolute necessity of the shipowners to increase income as a solution to the rise in expenses, which conditions the implantation of new types of units.

HYDROFOILS

Following the chronological criteria, the HSC appear in the Canarian waters in 1966, when on the 5th August 1967, the hydrofoil *Corsario Negro*, (Marítima Antares Company), of the Dolphin class, designed in USA by Grumman, carried out its trial trip between the two capitals of province, Santa Cruz de Tenerife and Las Palmas de Gran Canaria, using in the stretch 53 miles, 75 minutes, at 43 knots. This boat, which would be the first to navigate in Spain, had a system of retractable foils, and laid down a bridge between the past and the modernity in communications. The first trip was fulfilled on the 22nd January 1968 and on 6th of June of the same year, the Marítima Antares decided to cancel the service. The main reasons were the bad weather, mechanical problems and the monopoly of the governamental shipping company, then in force.

The 2nd October 1970, the hydrofoil *Reina de las Olas,* Supramar PT 150 model, much larger and of more potency (Naviera Espanor, subsidiary of the John Prestus S/A of Bergen that had built the hydrofoil in the shipyard Westermoen, Mandal, Norway) was handed over to the shipowner John Presthus. It was built in Norway under the licence of Supramar, and arrived to Arrecife on November 19th 1970, sailing from Mandal, with various stopovers. It made the journey between Santa Cruz de Tenerife and Las Palmas de Gran Canaria in 90 minutes, at 36 knots. It had a capacity for 250 passengers, 34 tonnes of cargo or 8 small cars, and was the biggest hydrofoil sailing in that moment. It suffered the same problems as the *Corsario Negro*, suspending its activity a few months after it began (Rodríguez, 2004).

HOVERCRAFTS

After the last experience, the first hovercraft arrived to the Canaries: Model SR.n6 MK 1 Winchester Class, built by the Westland Aircraft Saunders Roe Division in 1965, with capacity for 38 passengers. It had navigated in Scandinavia under the name *Scanhover* and arrived to S/C de Tenerife on the 27th February 1967, but was not successful. Two more units of the last type arrived to Las Palmas on the 15th November 1968. They had been rendering their services between Naples, Capri and the island of Ischia and, after realising various technical trials around the coasts of the Islands, with numerous guests on board, they did not come into service, even though the incorporation of the bigger model BH-7 with capacity for 138 passengers, had been planned.

Deprived of these two fast units, which discouraged the renovating vocation of the population, the Canaries remained one more decade without enjoying the benefits of the high speed crafts, which circulated, without complications, in the seas allover the world.

JET-FOILS

The jet-foils were incorporated into our waters by the company Trasmediterránea, sailing between the islands of Tenerife, Gran Canaria and Fuerteventura. The first one was the *Princesa Voladora,* built in 1976 by Boeing Marine Systems in Seattle, USA, and which carried out its sea trials on July 27th 1980 and its first journey on the 7th August 1980. The 14th of April 1981, it was substituted by the jet foil *Princesa Guayarmina*, built by the same firm in 1981. It sailed 10 years for Trasmediterránea. Just as the *Princesa Voladora*, it was sold to the company Far West Hydrofoil Co., in November 1991, where it sailed under the name of *Cacilhas* (Jane's 1994-1995). Considering the obtained success, two more modern units were bought with technological improvements and a capacity of 16 more passengers. The third jet-foil, *Princesa Guacimara*, also built by Boeing in 1981, sailed 9 years for Trasmediterránea, later sold to the same company as the former ones, where it was baptised as *Taipa* (Jane's 1994-1995). The *Princesa Guayarmina* and *Princesa Guacimara* established on 16th January 1982 the first fast maritime bridge between the two Canarian capitals, (Díaz Lorenzo, 1998). They competed directly with the aeroplanes, due to their speed and as well as due to the fact that linked two Canarian capitals, traveling from one centre to the other.

On 31st July 1990, the new jet-foil *Princesa Dácil,* built by the Kawasaki Heavy Industries, in Kobe, Japan, was delivered (Trasmediterránea), and on the 30th October of the same year it fulfilled its first journey between Las Palmas de Gran Canaria and Santa Cruz de Tenerife. This unit came with improved features, especially regarding soundproofing, turbine control, deck design, incorporated black boxes, etc. On the 7th September 1991, the *Princesa Teguise* came into service, also constructed by Kawasaki in Kobe, improving preceding vessels, consolidating the maritime bridge, which they covered at 43 knots, relying on attractive advertising campaigns. Both units had a capacity for 286 passengers (Díaz Lorenzo, 1998) (Jane's 1994-1995). The scarce profitability, the price increase of fuel and the competition of the catamarans took Trasmediterránea to put them for sale beginning 2004, as announced on its web page (Trasmediterránea, 2004).

FIRST CATAMARANS

In 1980, the company Alisur S.A. bought the catamaran *Alisur Azul*, ex–*Westjet*, built in Mandal, Norway, by the shipyard Westermoen Hydrofoil A/S in 1976 (Jane's 1994-1995). It was the first catamaran of gas turbines in the world. At first, it linked the two Canarian capitals, but due to a lack of profitability, it was moved to the Arrecife – to the Puerto del Rosario route. Later, it linked Corralejo with Playa Blanca, up until 1983, when it was transferred to Lebanon, and later to Cyprus, San Carlos de la Rábida, returning to the Corralejo – to the Playa Blanca route, until it was sold in 1986.

The *Alisur Amarillo* built in 1974, 211 passengers (Jane's 1994-1995) by the same shipyard as the last one, arrived to the island of Lanzarote in 1982, to link Corralejo with Playa Blanca. In May 1982, it was moved to the route Los Cristianos - San Sebastián de la Gomera. But three months later, it ended its service due to operative and economic reasons. After fulfilling other inter-insular trips, it returned to its first route, finishing in 1986, being incorporated into the Mediterranean and, later, into the Caribbean.

These units could not compete with the jet-foils in the trips from S/C Tenerife - Las Palmas, nor with the conventional ferry *Benchijigua* between Tenerife and Gomera, since they lacked cargo capacity.

HYDROFOILS

On October the 27th of1989, the Naviera Mallorquina (subsidiary of Trasmediterránea), started a route between Lanzarote and Fuerteventura with its hydrofoil *Tiburón*, of the Kolkhida class, built in 1988 by S. Ordzhonikidze Shipyard, Poti, Georgia, 155 passengers and 34 knots. It had sailed between the Balearic Islands and linked the islands of Fuerteventura and Lanzarote, with a duration of 20 minutes. It did not have the expected results and returned to the Balearics.

Trasmediterránea received the first hydrofoil, *Pez Volador* in 1986, followed by the *Barracuda* and the *Marrajo* in 1989, and the *Tintorera* in 1990. They had been built by Rodriguez SpA, between 1988 and 1990, with a capacity for 220 passengers the first one and 204 the remaining three (Jane's 1994-1995). The *Barracuda* was the first to arrive, after sailing in the Straight of Gibraltar it was incorporated to the route Los Cristianos-San Sebastián de La Gomera on the 1st of August 1989. The *Pez Volador* and the *Marrajo* joined the same route. The duration of the trips was: Las Palmas - S/C Tenerife, 80 minutes; Las Palmas - Morro Jable, 90 minutes; Los Cristianos - S.S. de La Gomera, 45 minutes (Jane's 2000-2001). Later, the last two were sold to the Ustica Line, in Italy (Díaz Lorenzo, 2004).

SURFACE EFFECT SHIP

A SES ship, the *Bahía Express,* which arrived to Tenerife on 13th February 1994, sailing from Poole, UK, with a Norwegian flag and called *Wright King*, also sailed our waters after being purchased by Fred Olsen. It had been built in 1989 by Brodre A/S, with 35,43 metres length, 11,20 beam and 330 passengers (Rodríguez, 2004). Its first trip was on the 13th May 1994 between Corralejo, Playa Blanca, Puerto del Carmen and Arrecife, with journeys between 15 and 35 minutes with a cruise speed of 40 knots and capacity to reach 50'. This was a wager of Fred Olsen for the high speed crafts and the possibility of introducing them in the Archipelago. On the 16th of June 1996, it carried out its last trip, moored thereafter in Santa Cruz de Tenerife and sold to the Panamanian company Trans Universal Seas Co.

MONO-HULLS

It is convenient to underline the presence in the Canaries of a high speed mono-hull of the Aquastrada TMV 114 type, built in Pietra Liguria by the Rodríguez SpA of Italy in 2002: the *Volcán de Tauro*, of steel hull and 113,45 metres, 41,5 knots, 928 passengers and 200 vehicles (Jane's 2001-2002), since it was the fastest and most potent craft in the Spanish marine merchantship. It arrived to Las Palmas from Messina on 6th May 2000, coming into service on 1st June, sailing between Santa Cruz de Tenerife, Las Palmas de Gran Canaria and Morro Jable in Fuerteventura, with the shipping agency Naviera Armas. The technical problems and the increase in the price of fuel caused its withdraw from the line, returning to the builder's shipyard in September (Díaz Lorenzo, 2004). It was bought later on by Eurolíneas Marítimas Balearia on the 2nd of March 2003.

The mono-hull *Almudaina,* of the Mestral class, (Monohull Excellent Sea-keeping Transport and Leisure Ship) arrived to the Canaries in the month of October 1996, to carry out a series of trials, especially between Los Cristianos and S.S. de La Gomera. It had been built in San Fernando, with a length of 95,20 metres, 37,5 knots speed for 533 passengers and 87 cars, and was acquired as a replacement of the hydrofoil that carried out that route and which suffered frequent breakdowns causing frecuent cancellations of the service. After 36 days in the Canaries, it was destined to routes in the Mediterranean between Levante and the Balearic Islands (Rodriguez, 2004).

From another perspective and beyond the events that affected this mono-hull, its features are noteworthy as an ideal unit for the Canaries, for its transportation of cargo and passengers, taking as a basis the data relative to various vessels that operate in the north of Europe.

Another mono-hull which navigated in our waters was the *GomeraJet*, 95 metres length and 32 knots, from the company Trasarmas (union of the Trasmediterránea and Naviera Armas), built by Mjellem & Karlsen Verft A/S, Bergen, Norway in 1995 for Starmarine Shipping A/S of Denmark. On the 28th of June 1999 it arrived to Tenerife and on the 2nd July it began to sail between Los Cristianos and San Sebastián de La Gomera in 40 minutes. The boat was scarcely profitable due to its breakdowns, manoeuvring capacity, scarce occupation and the ecologist campaign on its effects on the colony of pilot whales existing between Tenerife and Gomera. Its service was cancelled in February 2000, returning to the Straight of Gibraltar and later, to Denmark (Rodríguez, 2004).

GREAT CATAMARANS

The Fred Olsen Company placed an order in Australia, to the Incat Australia Pte Ltd., Hobart, for three catamarans to operate between Santa Cruz de Tenerife and Agaete, Gran Canaria. These were: *Bonanza Express, Bentayga Express* and

Benchijigua Express, all 95, 47 metres and 38 knots (maximum speed 42 knots), with 755 passengers and 230 cars the first one, while the other two could take 900 and 260 (Jane's 2001-2002). The first two were built in 1998 and 1999, while the last one was built in 2000. The three have a service speed of 38 knots and maximum of 48, lightweight. Their manoeuvring facility is such that they can turn 360° in 1 minute and can go from 43 knots to 0 in 160 metres.

The *Bonanza Express* came into service in 1999, arrived to S/C Tenerife on the 22nd of March 1999, travelling from Tasmania by the South of Africa, being incorporated to the line between Santa Cruz de Tenerife and Agaete (Gran Canaria). Nowadays this vessel covers the line Los Cristianos (Tenerife) Valverde - (El Hierro) – San Sebastián de La Gomera. The *Bentayga Express* arrived to S/C Tenerife on the 22nd of October through the Channel of Panama. Even though it was initially foreseen for the route Tenerife-Gomera, this was not possible due to a lack of installations, so it was assigned to the route Tenerife - Agaete on the 25th of October 1999.

The *Benchijigua Express* launched on 20th December 1999 and handed over on the 6th January, sailed to San Sebastián de La Gomera through the Pacific, arriving on the 27th January. Since the 27th January 2000, it linked the ports of Los Cristianos (Tenerife) and San Sebastián de La Gomera (Gomera) and from the 1st of April 2003, in its last journey of the day it made a stopover in Santa Cruz de La Palma (La Palma) (Díaz Lorenzo, 2004). The *Benchijigua Express* and the *Bentayga Express* actually changed their names into *Bentago Express* and *Bencomo Express* and both are sailing on the route between Santa Cruz de Tenerife and Agaete.

The three catamarans in service offer a great quality and efficiency in their service, both for passengers and merchandise.

The *Bocayna Express* with a length of 66,2 metres and 32,8 knots of speed, built by Austral Ships in Perth, Australia in 2002, arrived to S/C Tenerife 2nd October 2003, through the Channel of Suez, and unites since 2003 the ports of Playa Blanca (Lanzarote) and Corralejo (Fuerteventura).

This year, Fred Olsen incorporated to its fleet the biggest phase multi-hull ferry in the world, a trimaran of Austral Ships, which s sailing between Los Cristianos – San Sebastián and Santa Cruz de la Palma since May 2nd 2005 with a cruise speed of 40 knots. Its length is of 126,7 metres, and its able to varry 1.291 passengers, 341 cars or 450 line metres of cargo plus 123 cars (Fred Olsen, 2005).

SMALL CATAMARANS

There is another company sailing between the Canary Islands with two catamarans of 40 metres length, 394 GRT, Garajonay Exprés S.L. built in Singapore in 1997 and who rendered their services in the island of Cebu, Philipines, where the low prices fixed by the Government made the line unfeasible, hence returning to Singapore. They were sold to the United Kingdom to sail in the Channel of La Mancha. Finally, with the names of *Garajonay* and *Orone,* they arrived to the

Canaries to render their service between the ports of Los Cristianos, San Sebastián de La Gomera, Playa Santiago and Valle Gran Rey (the last three in La Gomera). The first of them arrived to Valle Gran Rey on 1st July 2002, while the second one did so in October of the same year. On the 6th of November they started to operate (Rodriguez, 2004) until today.

The practical orientation of the high speed crafts in the Canaries has been polarised in three very defined ways. Firstly, the super catamarans built by Incat in Tasmania and operated by the shipping agency Fred Olsen; secondly, the jet-foils built in Japan by Kawasaki under licence of the American Boeing and under the protection of the Compañía Transmediterránea; and thirdly, on the island of La Gomera two 40-metre catamarans built in Singapore by the Kvaerner Fjjelstrand for the Garajonay Exprés, S.L.

From a perspective of future, maybe the alternative that best distinguishes the prevalence of the maritime connection of the islands are the catamarans belonging to Fred Olsen as opposed to the other two existing options. These fast vessels have a clearly different structure with capacity to transport vehicles, on the one hand, and the comfort of navigation on the other, which determine their suitability for the Archipelago. The arrival of the trimaran for Fred Olsen and the announcement to sell the Trasmediterránea jet-foils' can mean the permanence of only the multi-hulls in the Canaries.

CONCLUSIONS:

1. The Canary Islands, with their special conditions for navigation, as corresponds to an extensive archipelago situated in full ocean, open to all seas, have been a true bank of trials for the high speed crafts. Six types of the most important HSC, both on a national scale and on a world scale, have sailed in its waters: Hydrofoil, hovercraft, jet-foil, SES, mono-hulls and catamarans, with unequal results.

2. The first HSC in Canarian waters were the two hydrofoils, arriving in 1960 and 1970, which remained in service few months due to operative and profitability reasons. After a brief experience with three hovercrafts, which after carrying out the trials, did not come into service, various hydrofoils arrived, belonging to different companies and which were progressively withdrawn from service, due to technical and operational problems, as well as to lacking cargo capacity. Neither the experience with an SES was satisfactory.

3. Later, three mono-hulls were incorporated and the jet foils from Trasmediterránea, these last three being the only ones to remain in service, untill June, even though there sale has been announced.

4. Finally, we would come to the actual catamarans, which link all the islands. The tendency seems to point to the fact that the catamarans, which for their cargo capacity, navigation safety and passenger comfort, will leave the interinsular transport exclusively in the hands of multi hulls in the coming future.

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EMBARCACIONES DE ALTA VELOCIDAD EN LAS ISLAS CANARIAS

RESUMEN

Para las islas Canarias, el mar es un camino de uso obligado y en cuya dependencia se ha basado el desarrollo económico de los habitantes del Archipiélago. La problemática del transporte marítimo interinsular ha sido y continúa siendo una preocupación constante y creciente hasta el momento presente, dada la casi nula capacidad de carga de los aviones que prestan servicios en las islas.

Las embarcaciones que comunican las islas han ido cambiando a través de los tiempos, y estos cambios han estado condicionados en gran manera, por las especiales circunstancias meteoro-oceánicas que rodean a la navegación en nuestras aguas. Estas circunstancias han supuesto que las islas hayan sido un verdadero banco de pruebas para los tipos principales de HSC: hidrofoils, air cushion vehicles, high-speed mono-hull crafts, SES, jetfoils and catamarans, en las que han navegado y donde han corrido distinta suerte.

INTRODUCCION

Si bien hasta hace pocos años la principal actividad económica del Archipiélago era la agricultura, dirigida tanto al consumo interno como hacia su comercialización en el resto de España, principalmente plátanos, tabaco, tomates, vinos, frutas tropicales, etc., esta situación ha cambiado y el 74,6% de la riqueza regional se produce en el sector terciario, fundamentalmente por el turismo o actividades ligadas a él.

En los últimos 80 años las comunicaciones interinsulares han sido preferentemente marítimas, en cuanto a mercancías, y aéreas en lo referente a pasajeros, ya que la capacidad de carga de los aviones que vuelan en Canarias es de muy escasa incidencia. La compañía Bintercanarias, que cubre la práctica totalidad del movimiento de pasajeros entre las islas, transportó en 2003 la cifra de 2.243.387 pasajeros.

Canarias la componen siete islas principales y varios islotes, con una extensión que varía entre los 1.928 Km^2 de la isla de Tenerife a los 227 del Hierro. La población canaria asciende a un total de 1.894.868 habitantes, de los cuales 915.262 viven en las islas occidentales, mientras que 979.606 lo hacen en las orientales. La meteorología viene caracterizada por la circulación de los vientos alisios, si bien puede completarse con las incidencias de los distintos tiempos atlánticos: monzónico de invierno, invasiones de aire polar marítimo, borrascas atlánticas y depresiones tropicales, que pueden afectar al litoral canario causando un fuerte oleaje, en ocasiones con olas de hasta 8 y 10 metros, que obligan a suspender la navegación marítima, si bien la altura normal suele ser de 2 metros. Ocasionalmente, se sufren temporales del E y S, que ocasionan cuantiosos daños materiales en infraestructuras portuarias.

El mar es, indiscutiblemente, una vía de comunicación útil y económica para todas las islas, por ello tienen una especial relevancia las circunstancias económicas en las que se desenvuelven el tráfico marítimo de las HSC: el excesivo costo de las modernas unidades, los elevados gastos de las infraestructuras portuarias, el consumo y el precio del combustible. Lo anterior se une a la imperiosa necesidad de los armadores en acrecentar los ingresos como solución a la escalada de los gastos, condicionando la implantación de nuevos tipos de unidades.

METODOLOGÍA

En base a las experiencias personales de los autores, en relación con la navegación en HSC, se inició una fase de recopilación de datos, tanto bibliográfica como de las compañías cuyas embarcaciones navegan entre las islas, a fin de estudiar las distintas trayectorias que las HSC habían tenido en aguas canarias, particularizadas para cada uno de los seis tipos principales de las mismas, con sus prestaciones, ventajas y problemas. Finalmente, se trató de llegar a las oportunas conclusiones sobre los servicios que prestaron en Canarias, así como los motivos que llevaron a la cancelación, o no, de sus servicios.

CONCLUSIONES

1. Canarias, con sus condiciones especiales para la navegación, como corresponde a un archipiélago extenso, situado en pleno océano, abierto a todos los mares, ha sido un verdadero banco de pruebas para las embarcaciones de alta velocidad. En sus aguas han navegado los seis tipos de HSC más importantes, tanto a nivel nacional como mundial: Hidrofoil, hovercraft, jetfoil, SES, monocascos y catamaranes, con desigual resultado.
2. Los primeros HSC en aguas canarias fueron dos hidroalas, llegados en 1960 y 1970, que permanecieron en servicio escasos meses por razones operativas y de rentabilidad. Después de una breve experiencia con tres hovercraft, que realizadas las pruebas no llegaron a entrar en servicio, luego llegarían varios hidrofoils, pertenecientes a distintas compañías, que fueron progresivamente retirados del servicio, debido a problemas técnicos y operativos, así como la no disponibilidad de capacidad para carga. La experiencia con un buque SES, tampoco resultó satisfactoria.
3. Con posterioridad, se incorporaron tres monocascos y los jet-foils de la Compañía Trasmediterránea, siendo dos de estos últimos, los únicos HSC, no catamaranes, que permanecían en servicio, si bien fueron amarrados y puestos en venta en el pasado mes de junio.

4.- Finalmente se llegaría a los catamaranes actuales, que unen todas las islas. La tendencia parece apuntar a que los catamaranes, por su capacidad de carga, seguridad en la navegación y confort del pasaje, dejarán en un futuro próximo el transporte interinsular en manos exclusivamente de multicascos.

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