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A growing gap between the integrated systems on the bridge and the end users : an approach considering safety and risk management

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A GROWING GAP BETWEEN THE INTEGRATED SYSTEMS ON THE BRIDGE AND THE END USERS

An approach considering safety and risk management

By

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred to me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the university.

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Abstract

Title of the dissertation: **"A growing gap between the integrated systems on the bridge and the end users. An approach considering safety and risk management".**

Degree: MSC

The dissertation is a brief investigation into the aspects of technology design regarding the seafarer and how the training of the seafarer on that technology is considered and carried out. The area of study is the bridge of a vessel, the bridge team management and the technology applied on it, specially the current integrated systems.

Aspects of how technology and automation in particular have changed the role of the Officers Of the Watch (OOW) regarding the task they need to perform, have been approached. Particular attention has been given to the human characteristics when interacting with this type of technology.

Safety and risk have been superficially touched upon from a Human Factor and Human Error perspective. Both terms seem to be important actors as causes of incidents and accidents. However, they involve certain indetermination in what they are or what they signify, which can serve to be depositary of other causes of accidents which remain hidden.

Different techniques in how to manage human aspects when assessing the risk are introduced. Industries with longer trajectories in this regard are using new techniques more concerned with the context on which the action is performed. Still, that is not the case in the maritime industry.

The regulatory framework in IMO, as well as in certain quality organisations, regarding the incorporation of integrated systems on the bridge and how is the human aspect considered in the process has been gathered and analysed.

In the concluding chapter a set of implications are provided regarding the findings to this investigation. Some recommendations are given to the need of a new conceptualization of Human Factor and Human Error, as well as more specification on the term “familiarization”. It is also recommended to make the model course regarding operational use of IBS for Masters and OOW mandatory.

KEYWORDS: Human Machine Interface, Training, Human Factors, Human Error, IBS, Technology, Bridge Team Management.

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List of Abbreviations

ATHEANA	A Technique for Human Element Analysis
BDEAP	Bridge Design, Equipment Arrangement and Procedures
BTM	Bridge Team Management
CBA	Cost Benefit Analysis
CBS	Computer Based System
COTS	Commercial-off-the-shelf
CPC	Common Performance Conditions
CREAM	Cognitive Realiability and Error Analysis Method
EPC	Error Producing Conditions
EUC	Equipment under control
FSA	Formal Safety Assessment
GEMS	Generic Error Modelling System
GPS	Global Prositioning System
HAZID	Hazard Identification
HEAP	Human Element Analysing Process
HEART	Human Error Assessment Reduction Technique
HFI	Human Factor Intergration
HMI	Human Machine Interface
HRA	Human Reliability Analysis
IACS	International Association of Classification Societies
IBS	Integrated Bridge System
IMO	International Maritime Organization
INS	Integrated Navigation System
ISM	International Safety Management Code
ISO	International Standard Organization
MAIB	Marine Accident Investigation Branch
MEPC	Martime Environmental Protection Committee
MET	Maritime Education and Training
MMI	Man Machine Interface
MSC	Maritime Safety Committee
NAV	IMO Subcommittee on Safety of Navigation
NRC	National Research Council
NTSB	United States National Transportation Safety Branch
NUREG	US Nuclear Regulatory Research
OOW	Officer of the watch
PES	Programmable Electronic Systems
PSF	Performance Safety Factors
RCO	Risk Control Options
SOLAS	Safety of life at Sea Convention 74
SSP	Siemens Schottel Propulsor
STCW	Standards of Training, Certification and Watchkeeping Convention 78 as amended
STW	IMO Subcommittee on Standards of Training and Watchkeeping
THERP	Technique of Human Error Rate Prediction
TIS	Task Interactive System
UK	United Kingdom

- Chapter 1 - Introduction

1.1.- Motivation

From the beginning of the studies in Maritime Education and Training (MET) specialization, the section regarding how the Officer of the Watch (OOW) was trained to handle the specific equipment on the bridge seemed particularly confusing.

In this sense, the training with specific technology seems always to be included under the term familiarization, which means very little at the time of regulating and establishing training. In addition, looking at the lack of standardization of bridges, it is really impressive how deck officers, moving from one bridge to another, are able to operate on the different bridges safely.

Having little experience in the maritime industry, i.e. reduced to the studies at WMU, with a Navy background as a deck officer, the perception of the author about the required training before being able to operate on board a specific vessel was strongly influenced by Navy practices.

In addition to the basic knowledge that involves the operation of a vessel at sea, the officer has to know and be trained in using the equipment before being appointed for duty. This is the normal practice; however, besides this strict system, problems in this aspect still exist.

Therefore, the main motivation at the beginning was to understand how the maritime industry deals with the training of the OOW on the specific technology and later how the seafarer is considered when the technology is incorporated.

1.2.- General Background

The 1980s was a time of big changes in the shipping industry structure. The world trade experienced important growth due to the globalization of the world, a growth that the maritime transportation had to follow. The vessels increased speed, capacity of transportation of cargo and efficiency for loading/offloading operations reducing the time spent in ports. At the same time, the price of fuel reached levels that had never been seen before and became a considerable operational cost (Tarver & Pourzanjani, 2003).

In response, shipowners started to manage costs and different practices turned to be a commonality. One of the practices was the incorporation of technology which got more presence on board vessels changing how the work was performed by humans and also the way the vessels were manned (Rowley et al, 2006).

At first, when the electronic equipment stepped into the navigation, it was used as a backup. For example, OOWs continued to use astronomical calculations and electronic navigational aids were used as a secondary mean. Radar was an excellent tool for navigators, for which they had to learn the principles of operation, capabilities and limitations. However, it had to be combined and cross checked with visual bearing. The real advantage that the Radar gave to the OOWs was allowing them to proceed safer in conditions of restricted visibility. Despite all these electronic applications, the OOW remained to be directly in control of the vessel's evolution (Muirhead, 1999).

After the 1980s, technology came on board taking over tasks that the OOW had to do by himself, changing a long tradition of navigation. Bridges today are provided with autopilot and Integrated Bridge System (IBS)/Integrated Navigation System (INS), which deliver a continuous amount of synthesized data from different sources regarding the situation of the vessel. The OOW has to interpret this data and act consequently through these complex systems again. These systems can take care of the navigation in automated mode, so the role of the OOW has changed from being the active actor on the navigation, to be a monitor of the automated system which controls the navigation (Lutzhoft, 2004).

Furthermore, electronic integrated systems are considered to be more accurate than ever before (Swift, 2004), more reliable than humans and capable of providing better situational awareness to the OOW. They make the bridge of a vessel resembling the cockpit of an air plane (Rowley et al, 2006). However, they did not substitute the presence of the human on board, only changed his task and reduced the number of persons performing watch.

Together with the mentioned changes, came changes in the knowledge and training that the OOW needed. All of a sudden, the knowledge and traditions of the art and science of navigation fell out of practice and navigators had to adapt to the new situation.

In sum, technology came on board the vessel due to economical reasons but later, considering technology as more reliable than the human being, the incorporation of technology had a strong component of safety in it. Today, competitiveness add even more value to keep high the rate of incorporating technology (National Research Council [NRC], 2004 as cited by Lutzhoft, 2004).

1.3.- The objective

Technology is being seen as a guarantee to keep a high level of safety and its application within the maritime industry allocates a good image of the industry. However, not always did this technology applied on vessels give the expected results (Lutzhoft, 2004).

To justify this shortage in performance of the technology, the immediate answer is found on the side of the users, who do not operate correctly the technology provided (Nautical Institute, 2007). Still, the technology provided on vessel bridges needs the presence of humans to perform as was designed, and normally it is the human who makes a wrong input, wrongly acknowledges an alarm, misinterprets information, and so on. But, is this shortage of technology an exclusive problem of the user?

The objective of this research is to answer the question whether there is a growing gap between IBS/INS and the Bridge Team Management (BTM), which is affecting the safety operation on the bridge. In the pursuance of this objective the research aims also to:

- Investigate in the Human Machine Interface (HMI) concept and how it is applied in the maritime industry.
- Investigate different perspectives of Human Factors and Human Errors, trying to find out whether the problem of the gap between integrated system and user is included in those two concepts or is assumed independently by the maritime industry.
- Determine whether it is possible to identify clearly the lack of proper HMI design as cause of accident, or it is normally included under Human Error.
- Investigate the current pertinent regulation addressing the incorporation of technology on bridges. Particularly, technology design and training of the users.
- To show by examples how safety operation on the bridge is affected when there is not a proper connection between the Bridge Team Management (BTM) and the IBS/INS.

1.4.- Methodology

The present research refers to a gap between the electronic integrated system on the bridge and the user. This gap is identified in what is called HMI, which is one of the main issues in this investigation, and the training of the users of technology.

To answer the question, this research has addressed how is and was considered the user in the design of IBS/INS and under what regulatory framework this technology is incorporated on board. Also, how the industry prepares the user of an IBS/INS to operate it safely.

In order to identify whether or not the gap between IBS/INS technology and the end users constitutes a safety problem, the concept of Human Error has been approached together with the Human Factor concept. Not only how these two concepts are taken in the maritime industry were studied, but also how other industries do in order to gain a broader picture. One of the aims of this approach is to investigate if is possible today to clearly attribute as cause of accident problems between the technology and humans beside the well known cause Human Error.

In this research, issues related to the high turn around of crews among different vessels have not been addressed directly. However, some mentions to these issues are made as a reality that interfere with proper training with the equipment installed on board.

The word technology used in this paper, was assumed mainly to refer to IBS/INS systems. The reason for this assumption is that the provision of integrated systems is a current trend on bridges, towards other subsystems are connected. Particular reference will be done to automation.

This research could not be provided with data that could have been used to clearly determine the percentage or proportion of participation of this gap between IBS/INS and end users in the affection to safety. On the other hand, important amount of the sources used, sustain the need of implementing further measures regarding the link between the technology and users, arguing that this aspect is affecting safety.

Starting with the analysis, Chapter Two is dedicated to the HMI concept and how it is considered in different industries. It will be shown that until the end of the 1990s there was no specific requirement to relate the technology with the user. It was a more technology centred era. Also, it describes the participation of ergonomics in the design of technology and what the roles of the user are when interacting with technology. At the end, one particular approach was carried out regarding the perception that users have whenever they have to interact with technology.

Chapter Three is intended to determine how the Human Factor concept is allocated when dealing with new technology in current days. Together with it, it will be mentioned the aspect of Human Error and what are the current techniques to analyse this aspect when assessing the risk. It was studied how the International Maritime Organisation (IMO) assesses human aspects, and what Human Reliability Analysis (HRA) techniques are in use by IMO. Since these techniques are being succeeded by the so-called “HRA second generation techniques” (Fujita & Hollnagel, 2004), brief approach to these will be done.

In Chapter Four a study of some relevant documentation was done regarding the implementation of technology on the bridge. It was divided between the mandatory current regulations and non-binding documentation. The reason was to indicate how these two groups of documentation address the aspects of HMI and training with new technology.

In Chapter Five the BTM is addressed in two different perspectives. One is considering the technology and human resources together and the other is considering only the human resources. The chapter also has two accidents in which the lack of an appropriate operation of the technology was present. It was attempted to analyse these two accident using the information provided in previous chapters regarding the HMI and training aspects. Some aspects of what happens when technology deteriorates are included.

In Chapter 6 the conclusions of this research are provided and some recommendations are given.

- Chapter 2 - Interaction between OOW and Technology

These days, the OOW has to operate a bridge populated with electronic devices. These devices take a big proportion of the task that in other times pertained to the OOW. The OOW turned to be the person who supervise the electronic devices.

In this chapter different aspects that affect the relationship between user and technology will be dealt with.

2.1.- Definitions of HMI and integration of safety in its design

The first definition is from the International Engineering Consortium (IEC). They define HMI as the area “where people and technology meet. This people-technology intercept can be as simple as the grip on a hand tool or as complex as the flight deck of a jumbo jet” (http://www.iec.org/online/tutorials/hmi/). It is added by IEC that HMI has as main purpose to make itself “self-evident”, and it must be what the user's expectations are regarding the execution of the task with that machine.

The second definition comes from the German delegation to the IMO/Sub Committee on Safety of Navigation (NAV): “the part of a system an operator interacts with. The interface is the aggregate of means by which the users interact with a machine, device, and system (the system)” (International Maritime Organization [IMO], 2007a, p. 37).

Both definitions agree that HMI is the point on which technology and human has to coincide in order to carry out the task. However, the German definition does not consider the user's expectations.

Other agencies have identified the aspect of integrating humans with technology calling it Human Factor Integration (HFI). In this context, HFI is perceived as the taxonomic use of applicable information about human characteristics as well as behaviour and causes of motivation to apply them in the design of systems. Regarding human characteristics, they involve the use of sciences as Psychology, Anatomy, Ergonomics, Biomedicine, among others, and combine them with those aspect of engineering and design of technology (Sea Systems Group,2006).

Another approach found of HMI is in the field of surgery. In this field HMI is perceived as a science that permits empathizing humans interacting with the environment, considering the technology they need to operate and consequently designing this technology with the knowledge acquired from human behaviour and expectations (Savatava & Ellis, 1994).

Again looking at IMO, the Maritime Safety Committee (MSC) Circular 878: “The interim guidelines for the application of Human Element Analysing Process (HEAP) to the IMO rule-making process”(IMO, 1998c, p. 1), has another definition of HMI. They define HMI as the area of study where the design of equipment is analysed with the human characteristics when using such equipment, with the purpose of achieving high level of efficiency in the task. The document adds that “the aim (of HMI) is to achieve uniform design and layout”(IMO, 1998c, Annex p. 7) using ergonomics and education and training.

Furthermore, the MSC Circular 878 includes a list of five areas when considering the Human Element[1]: Technical, Management, Manning, Work Environment/conditions and Training. Specifically, the HMI is included under the Work environment/conditions referred as Man Machine Interface (MMI). It is further clarified that MMI is a "technical issue that has implications on the work environment"(IMO, 1998c, Annex p. 5). However it is not included in the Technical area[2].

Among the definitions cited above, only those from IMO do not consider

1 In Section 3.1 is described what is referred by IMO as Human Element.
2 See Appendix B

user's expectations. On the contrary, the others definitions cited have considered that the HMI is the link between users and technology, which has to be designed considering user's characteristics and expectations.

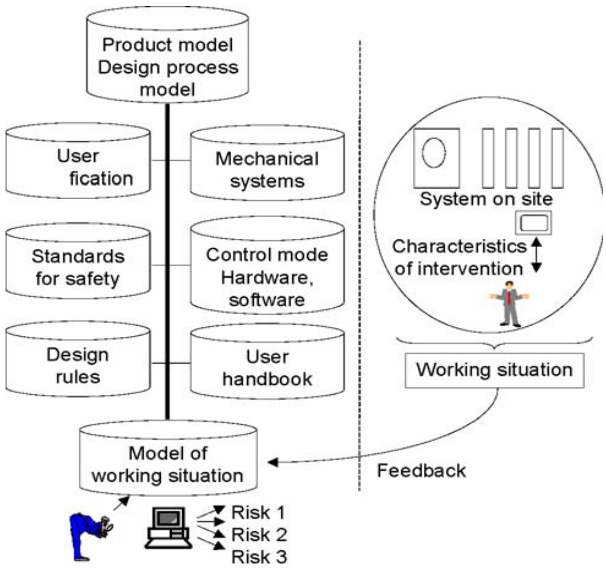


Figure 1: Integration of working situation in design (Bernard & Hassan, 2002, p. 2)

Incidentally, the main reason to consider the user when designing the HMI is to diminish to the minimum possible the probability of error by the user, which is a safety issue. In this regard, it was found that developers and producers of technology do not integrate the safety concept until the last part of the design. Actually, the issue of safety is addressed at the last stages of the product' design, consequently very difficult of doing it properly (Bernard & Hassan, 2002).

Normally, the inclusion of safety is done mainly having in mind the rules and regulations. Furthermore, since there is not a standardized criteria in how to integrate safety in the design stages and that normally is considered a hindrance for the designer, this aspect is frequently addressed in informal ways (Bernard & Hassan, 2002).

Bernard & Hassan (2002) made this discovery using an offset printing line as a case study. They developed a model, shown in Figure 1, where safety can be integrated at early stages of the design. By using this model, the designers have to imagine the instances of human intervention and undesirable events and develop solutions. The solutions have to be weighed by the operators regarding whether the solutions change any ergonomics aspect, or reduce visibility. This model is applicable for any other field of technology production (Bernard & Hassan, 2002).

2.2.- Ergonomics and HMI

It has been seen in the definitions of HMI the need for designing it under Ergonomic principles. In this section it will be mentioned what Ergonomics is, how it is regarded today in the maritime industry, and the advantages of using ergonomics not only in the design of new bridges, but also in the normal life of working situations.

Wilson (2000) says that ergonomics is the "theoretical and fundamental understanding of human behaviour and performance in purposeful interacting socio-technical systems, and the application of that understanding to design of interactions in the context of real settings" (Wilson, 2000, p.557).

Adapting this definition to the bridge of a vessel, ergonomics would mean the corresponding understanding of the standard characteristics of the OOW when operating the electronic systems on the bridge, considering the devices of the system that interacts with the user, e.g. displays, arrangements and disposition of the devices, shapes and types of controls and alert devices.

Nevertheless, the determination of the standard characteristics of an OOW represents a real problem in the shipping industry; vessels can be manned by officers from all over the world, involving different cultures, values and language (Squire, 2005).

Moreover, bridges are not always designed from scratch as in the case of new buildings; updating the bridges with new technology is a normal practice in shipping. Different brands of equipment are interacting with the user, and the user has to accommodate himself to the different interfaces (Rowley et al, 2006). Therefore, the intervention of Ergonomics not only in design of the technology but whenever changes take place on board would be the best.

At first, the motivation for introducing technology was mainly due to saving costs and technology producers were more interested in satisfying ship owners' expectations. In this regard the technology for the vessel was more designed having in mind what the technology should perform to satisfy the needs of the customer. In other words, the design of that technology was more technology-centred. (Rowley et al, 2006)

Consequently, the application of Ergonomics in the maritime industry was not from the beginning. At first, these principles were perceived by the industry in a negative way, as affecting the normal traditions and customs. While in the late 1990s there was no strict regulations regarding the design of bridges, nowadays principles of design using Ergonomics are more common. (Helm, 2008).

As a result, the maritime industry today has a public concern about ergonomics design on vessels. Major stakeholders and international law making bodies are using this aspect in the design of the bridge of the vessels with a relevance that was not common 15 years ago[3].

In essence, the role of Ergonomics is two fold: to understand purposeful interactions between people and artefacts; and to design interacting systems, maximising the capabilities, minimising the limitations, and satisfying the expectations of the users. Therefore, Ergonomics can provide important feedback after having provided the vessel with new technology, which would lead to further improve future systems.(Wilson, 2000)

3 Chapter 4 includes some of these documents.

Therefore, the potentiality of Ergonomics to understand purposeful interactions could lead to a better understanding of the wrong actions committed by the user of technology and to switch from technology centred-design to user-centred design (Wilson, 2000).

In addition, Ergonomics provides designers with the information about what are the best ways by which the users will perform better with technology (Wilson, 2000). Ideally, those ergonomic scientists should need to work closely to the designers and users, providing intermediation between the needs of the users and the limitations of the designers. Normally, designers and users think in a different way about technology (Lutzhoft, 2004; Kristiansen, 2005; Reason, 1990).

Designers use a causal model based on what is the reaction of the system after applying certain variable or input. Users, on the other hand, use the perspective of how a certain variable can be applied to the system in order to achieve the desired result (Lutzhoft, 2004). The users are more interested on the intended result from using technology; designers pursue a permanent search to further improve the design of technology.

Furthermore, designers and developers of technology tend not to consider the user in early stages of design. For example, in order to apply the safety regulations, designers put some barriers that could reduce the visibility or the accessibility to the system by the users. Then, when the system is in normal operation, the users can find the system's safety-barriers to be not understandable, and consequently eliminating or disabling them, or even they can start performing procedures which are away from those procedures designed by the designers (Bernard & Hassan, 2002).

In this regard, Lutzhoft (2004) and Rowley (2006) say that there is proof showing what designers and developers put on the display devices, for example, not necessarily what the mariners want to see.

In addition, many system designers perceive operators (users) of the system as unreliable and inefficient, and then they intend and foster the substitution of the user by incorporating automated devices in the task to make it safer (Reason, 1990). However, the outcome of this technology incorporation does not result always in the desired level of safety, particularly when technology is designed and incorporated without considering the user and without giving him or her the corresponding training (Lutzhoft, 2004; Rowley, 2006; Dekker, 2006).

As an illustration, there is a case where a company decided to incorporate an Electronic Chart System after one of its ship grounded. Soon after, the company had another ship grounding with heavy damage on the hull where the Electronic Chart System was installed but not used as it should be. The report of this accident did not include as direct cause of the accident the lack of proper use of the Electronic Chart System. However, the report specifically mentions that the Master was not using it and he had never received training on its operation (Marine Accident Investigation Branch[MAIB], 2007).

Another important advantage of using Ergonomics as often is possible, is that it has a consequence in the way the organisational culture perceives Human Error. Wilson (2000) states that the blame culture is against a sound application of ergonomics. The reasoning behind it is that blaming the humans without asking why he or she made this error, there will be no progress. Only by eliminating the blew fuse, the situation that led to the error, will be brought back (Wilson, 2000).

One example is the oil spill incident from the Tanker Vessel Randgrid in 2000. The Randgrid was unloading crude oil at Tetney terminal monobuoy, in the United Kingdom (UK). It was moored as usual by the bow. A hawser was fixed through a chafing chain stuck by the chain stopper. During the night there was an unintentional operation of the chain stopper from the bridge which provoked the loosing of the mooring manoeuvre and consequent disconnection of the hoses. The outcome of the incident was an oil spill of 12 tonnes of crude oil (MAIB, 2002).

The aperture of the chain stopper was controlled from a multifunctional console on the bridge by pressing the F9 button. Presumably, with the chain stopper control displayed, someone tried to shut down the hydraulic pumps for which, coincidently, F9 had to be pressed. The Company conducted an investigation and found that the cause was Human Error. The error was that someone pushed a button on a keyboard selecting the wrong display (MAIB, 2002).

Had the company introduced the application of Ergonomics, possibly in the first place the chain stopper and hydraulic pumps would not be operated from the same console. Also, the cause of the accident could have been completely different, which probably aimed to improve the design of the HMI in this case.

2.3.- The OOW perception of technology

It has already mentioned, the importance of the user's characteristics and expectations for the HMI. The expectations that users have about technology are influenced by the way they perceive it (Rowley et al, 2006). This section describes how the user's perception of technology was 25 years ago and how it is today.

When the trend of introducing technology increased notoriously in the 1980s there were many uncertainties which raised even more questions and many researches tried to forecast what would happen. The problem of having only one man performing watch on the bridge or the existence of dual purpose officers, put serious challenges for Education and Training and for regulatory framework. At that time, the opinion of seafarers about technology was "Too many but not needed; Not reliable enough; Poor operational manual; Configuration of the bridge not comprehensive enough (Muirhead, 1992, p. 7).

Again, in the research of Lutzhoft (2004), her findings showed that seafarers, not totally refusing, are not very keen in using the technology and they are least keen when they are under pressure. According to her findings, seafarers prefer to keep the method they know already[4] (Lutzhoft, 2004).

4 One example of this is given in Section 5.2. Particularly the reaction of the Second Officer when he did not understand the evolution of his vessel.

In 2007, in an article that appeared in Alert, one master wrote about automation and Standard of Training, Certification and Watch keeping 1978 Convention as amended in 1995 (STCW), and linked the both with the need for having an electronic officer in the Safe Manning Certificate. He said that one of the goals of automation is to reduce costs and he identified that one of the main problems with automation is that it becomes unreliable when a failure or unexpected result arises. This failure causes the crew to become overloaded because they have to switch the system to manual and wait for shore personnel to fix it. At the end, he added that, if no solution is found to this problem, "automation just for the sake of saving costs is an accident waiting to happen..."(Jiménez, p. 3, 2007).

The perception narrated above about automation is clear. “Automation is great when it works”, according to Lutzhoft (2004, p. 1). Users of technology tend to lose trust on technology when failures appear (Bainbridge, 1983), and consequently tend to by pass the technology introducing themselves in the task.

In addition, there are findings of scary perceptions of the integrated systems by seafarers. This perception leads the users not to use efficiently the tool that they are supposed to operate. This behaviour is even more dangerous than taking the way of using the equipment with the possibility of making a mistake (Rowley et al, 2006).

Furthermore, bridges designed to be operated with an automated system are not so handy to be operated manually. Particular skills and dedicated personnel are required, who are no more available as they used to be. Training the users in equipment functionalities, limitations and capabilities is the only way for seafarers to become familiar with and attain the necessary trust in the equipment (Rowley et al, 2006).

Nevertheless, there are samples where seafarers are appointed on-board without knowing how to operate the equipment (IMO, 2003b).

2.4.- Role of the OOW when interacting with technology

This section will show how the interaction users and technology takes place from the side of the users and what the factors are that contribute to the HMI. Users who interact with technology, generally play three roles: monitor, collector of information and actuator (Lutzhoft, 2004).

Starting with the monitoring role, the OOW has to monitor that the technology is performing according to his intentions, e.g. following the planned route, adjusting speed to arrive on the expected time, and so on. The OOW is not directly involved in the navigation any more. When something goes wrong the OOW will take notice after the system indicates it; therefore, the OOW all of a sudden will have to adjust himself or herself from normal operations to abnormal operations and try to manage the situation.

Unfortunately, studies have shown that humans beings are poor monitors of the automated systems. Humans tend to rely more on the warnings and emergency alerts than on their own checking processes putting much trust on the systems. Lutzhoft & Dekker (2002) made these assertions studying the outcome of the accident of the Passenger Vessel Royal Majesty, in June 1995.

Very briefly, none member of the BTM realized that the Global Positioning System (GPS) receiver had changed to Dead Reckoning Mode. This device was providing position to the INS which was in automation mode, and did not recognize any hazard in the change of mode of the GPS. The vessel went off track 17 miles and grounded. Nobody was alerted of what was happening until too late, nothing could stop the grounding (National Transportation Safety Board [NTSB], 1997).

Also, users tend to consider a system that has been working without failure, to be less prone to fail. When nothing wrong is happening, the task of monitoring the system is almost meaningless, which makes the monitor not to be very attentive to it (Lutzhoft & Dekker, 2002).

On the contrary, when something wrong occurs unexpectedly, a high level of attention is needed to understand what is happening, acknowledge the malfunction and react accordingly. This drawback in the monitoring role of the user was acknowledged recently by IMO by the following statement where it is analysed the use of HRA in the Formal Safety Assessment (FSA) and is specifically pointed out that technology can create "long periods of low workload when a high degree of automation is used. This in turn can lead to an inability to respond correctly when required" (IMO, 2007c, p. 26).[5]

Other industries can allocate the task of only monitoring, indicating that if something goes wrong, another person more qualified has to be called for to take care of the malfunction (Bainbridge, 1983); unfortunately, this possibility is not available on a ship. The OOW can call the Master when the former does not understand the situation; however, nothing assures that the Master could have more skills than the OOW to manage a failure in technology.

Another aspect to consider in the monitoring role is the fact that technology today does not show the user what is happening inside it. This reduces the user's comprehension of its role as monitor of the system and raises uncertainty of what to monitor. Technology has put at least two layers among the intended result and the user. Starting from the user, the first layer is the HMI and the second layer is the "Task Interactive System"[6] (TIS) (Reason, 1990, p. 174). The latter is the part of the system at the lowest level which directly controls the execution of the task (Reason, 1990).

For example, the OOW has to control the course of a vessel. At present, the vessel will have an autopilot system which will receive the intended heading information from the OOW as an input. The input is done through the HMI. The autopilot will send the signal to the so called TIS, which at the end will control the rudder position in order to put the heading of the vessel on the ordered course. After

5 Further reference to the Human Reliability Analysis is made in Section 3.3
6 Section 4.2, ISO 17894 refers to the Task Interactive System as Equipment Under Control.

the TIS has performed the task, it will send a signal back to the HMI which will present it in a display, informing the user that the order is being executed. In the meantime, the user has no idea how the rudder is controlled.

Another contribution to the problem of monitoring technology by OOW is given by Barnett (2007). He confirmed the weak monitor capacity of the seafarer and highlighted the occurrence of inadvertent erroneous actions that can cause an accident delayed in time. These actions are called latent errors and bring about new sources of accidents (Barnett, 2007).

The second role is acting as a collector of information. Lutzhoft & Dekker (2002) have determined that when collecting information, the user has to integrate the information given by the system with the normal practice, rules and regulations to give it sense in order to accomplish the task.

This role is affected by the fact that the information is coming from different types of equipment made by different manufacturers, which signifies different HMI designs. Special care in this role regards the mode awareness. This mode will determine which information will be displayed. Unfortunately, studies have shown that users tend to assume that the information given by the system is accurate without any kind of verification, which at the end lead to bias the decision of the users (Lutzhoft & Dekker, 2002).

The third role mentioned is the actuator, on which the user having monitored the system, collected and integrated the information provided, is able to make a decision and take the necessary action. Normally, this action is performed using the same system, which will be updated with the outcome of the new action and will be displaying feedback information (Lutzhoft, 2004).

The three roles described above are performed permanently and without specific order. The user is a monitor and also a collector of information, or could be introducing an action while monitoring the system, and so on. The level of performance of the user in whatever role will be strongly influenced by the knowledge they have about the equipment (Dekker, 2006).

In this regard, studies found that users often have some buggy knowledge of the equipment (Dekker, 2006). They know how to operate it but they do not know its limitations and capabilities. In the case of seafarer, it was found that they are not familiar with the emergency procedures after a failure on the equipment. According to an United States NTSB' study cited by Rowley et al (2006), in which 100 accidents were analysed, 35% of the casualties were found with a contributory cause the “inadequate knowledge about the equipment”(p. 19).

Coupled with the necessary knowledge about the equipment, Dekker (2006) established that that knowledge should be organized in the user's mind and the user should be able to call for it according to the context of the situation. Otherwise, the user could have acquired the knowledge but not be able to use it. Therefore, Dekker (2006) claims that it is requisite that the users learn about the equipment and practice with it in order to internalise the knowledge.

However, with some automated systems the aspect of organizing and internalising the knowledge is difficult, because automation had reduced the chances for seafarers to have hands-on experience (NRC, 1994). “Computers can increase system reliability to a point where mechanical failures are rare”(Decker, 2006, p.151), leaving not many opportunities to the users to keep the skills high to manage system malfunctions.

- Chapter 3 - The Human Factor

"People remain a basic component with all their strengths and weaknesses which can both cause a disaster or prevent it" (O¨Neil, 2001a, p. 1)

The term the Human Factor is used with different meanings and this Chapter will mention different definitions of the Human Factor. Special mention will be placed to the aspect of Human Error.

3.1.- Conceptualization of the Human Factor

There is an indication that 80% of accidents have Human Factor in its causality chain (Hetherington et al, 2006). According to the literature reviewed, it was found that the term Human Factor is being used to refer either to the people inside the organisation or the factors that influence behaviour or to a field of study.

Starting with the Human Factor as people inside the organisation, Mr William O´Neil (2001) declared that the seafarer is the "the human factor that operates at the cutting edge of the sea transportation"(p.1). He refers to it as the core of the industry, who has the final control and the responsibility of the safe and efficient waterborne transportation.

The German delegation to the IMO/NAV subcommittee, submitted recently a document with the following definition of the Human Factor: "workload, capabilities and limits of a user trained according to the regulations of the organisation[7]"(IMO, 2007a, p. 37). Moreover, IMO has another term when addressing the people in the organisation, and that term is the Human Element. Human Element is defined as a "complex, multidimensional issue that affect maritime safety"(IMO, 2003c, p. 3) and needs particular attention in order to understand it.

7 In the cited document, the term Organisation is referring to the IMO.

In 2005, the United States delegation to the MEPC submitted a document acknowledging that the concept of the Human Element has to follow the current situation of "technology, safety culture and vessel operations"(IMO, 2005b, p. 1) and a systematic approach was needed. A check list to organize the work on Human Element aspects is provided, which was adopted from check list that the petrochemical industry uses to manage changes of any aspect in its organisation[8] (IMO, 2005b).

Nevertheless, Graveson (2005) indicates that both terms, Human Factor and Human Element, are used in shipping indistinctly to refer to seafarers matters, but often these terms are not "properly addressed"(p. 1).

Following, referring to Human Factor as the factors that influence behaviour, the European Commission (2001) in a research and development study, highlighted that in any means of transport the presence of human beings and their relation with the machine is essential. For that, they consider all aspects of the Human Factor that have an outcome on the behaviour of individuals, which consequently have an impact on the safety and efficiency of transportation.

Thomson (2008), points out that there is no standard criteria in what is included inside the Human Factor that affect human behaviour. He sustains that it is common to confuse in the causes of an accident the Human Factor with a "symptom or outcome"(p. 2) of a certain Human Factor. He considers that, so far, there is agreement in the following human factors:

- fatigue;
- alcohol and drugs;
- crew qualifications and training;
- workplace;
- sensory overload;

8 See Appendix A

- fitness including mental factors;
- crew communication difficulties;
- law of conservation of energy including procedures and operating manuals; and
- deliberate or wilful behaviour.

Thomson (2008) specifically excludes from Human Factor the situational awareness, which he says is an outcome or symptom.

In third place, assuming Human Factor as a field of study, Squire (2005) defines Human Factor as the "body of scientific knowledge relating about people and how they interact with their environment, especially when working" (Squire, 2005, p. 5). Sea Systems (2006) add more participation of the so called soft sciences in the concept of Human Factor: "an engineering discipline that applies theory, methods and research findings from Ergonomics, Psychology, Physiology, Anatomy and other disciplines to the design of manned systems" (Sea Systems, 2006, p. 1-12).

Similar to the previous definition, Earthy and Sherwood (2007) identified that the Human Factor pertains to the human science and is affected by three aspects:

- Human engineering - looking forward for the optimization of the human and machine performance;
- Safety – identifying and assessing hazards to health in the operation of the ship; and
- Health and Safety – identifying the risk when the ship is working in normal or abnormal situations.

3.2.- *Human error and Technology*

Normally a wrong operation of technology on the bridge is attributed to Human Error. This usually leads to the incorporation of further technology, even more complex (Lutzhoft, 2004).

At first, Kristiansen (2005) citing statistics, places that participation of Human Error in accidents is between 75% to 90% (p. 314) of the cases, which is similar to the information from Hetherington et al (2006) referring to the Human Factor. He found, that the term Human Error is not a straightforward concept, so he questions the accuracy of the statistics.

Furthermore, Kristiansen (2005) says that the term Human Error involves a generalization where many things can fit in to it, which could be leaving no side to determine other potential reasons for the wrong action committed. He characterizes Human Error as a vague concept and the perception of it is highly influenced by the background of those investigators appointed to analyse the Human Error. Also, he argues that this generalization of the Human Error as a term on which failures can be justified, it is also used by the designers of technology as a way to "get clear of responsibility for problems not considered as technical"(p. 42).

In addition, Fujita & Hollnagel (2004) shares with Kristiansen (2005) the opinion that Human Error is not a clear concept. They back the idea that when an accident occurs, it is because there are surrounding error-prone situations or activities which lead to the particular error of a person or group of persons. Furthermore, they consider that attributing everything to Human Error is "fundamentally a social and psychological process and not an objective, technical one"(Woods et al, 1994 as cited by Fujita & Hollnagel, 2004).

Moreover, the United States Nuclear Regulatory Commission Office of Nuclear Regulatory Research-NUREG- (2007) has launched recently the User's Guide of its HRA technique[9]. In this publication there is no definition or assumption

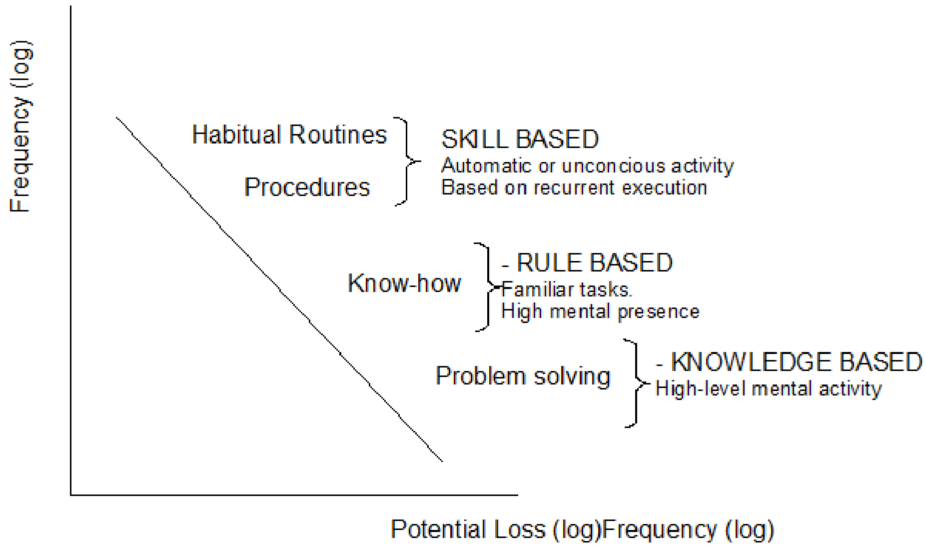
9 It refers to the HRA technique ATHEANA which is briefly described in Section 3.4

of the term Human Error. It is only stated that the “term Human Error is only used in a very general way, with the terms *human failure event* and *unsafe action* being used to describe more specific aspects of human errors”(United States Nuclear Regulatory Commision Office of Nuclear Regulatory Research [NUREG], 2007, p. xvi).

Regarding how the background of Human Error investigators influence the result of the investigation, Dekker (2006) cited a research with the purpose of identifying errors in a normal watch of a traffic control tower. The researchers used two groups of investigators to spend time observing normal watches of an air traffic control tower. One group was composed of traffic controllers and the second group was composed of experts on psychology and psychiatry. Both of them identified Human Errors in the performance, but the errors identified were dissimilar between both groups (Dekker, 2006).

Incidentally, there is the common assumption that whenever a failure happens, Human Error should be involved. Dekker (2006) and Reason (1999) sustain that there is not such easy determination. The system when it is working it needs the interaction with the human, who is connecting the technology outcomes with the environment. The assumption mentioned is backed with another assumption that the electronic systems are more accurate than humans, that they are “safe and well-functioning systems”(Dekker, 2006, p. 76).

Figure 2: Human performance levels (Kristiansen, 2005)



Conversely, the problem with the two previous assumptions is that systems are designed to be operated by humans, at least in the case of the shipping industry so far. Therefore, it is the combination user and technology that creates a further system in which both limit or enhance each other's performance. In this reasoning, how the HMI is designed plays a particular and important role.

Further, Rasmussen (1982) cited by Reason (1990), provided a classification on the types of errors. This classification of errors is called the Generic Error Modelling System (GEMS), and is based on categorization of three different human performance levels:

1. Skill based. In this category slips and lapses of the skill based performance are located. The error normally is originated by a departure from a well-established routine (Reason, 1990). Performance in this level is the result of “highly trained tasks” (Kristiansen, 2005, p. 395) that are carried out unconsciously by the user.

2. Rule based. This category is related to the procedures to follow, facing certain situations. The user needs to be trained in this procedures.
3. Knowledge based. This category is when the user has to solve an unexpected problem. The user has to integrate his or her system's knowledge, consider the context and solve the problem. In this category, the users have good experience using the technology, however, they can behave as novices when facing a new situation (Reason, 1990).

(Kristiansen, 2005)

Also, Kristiansen (2005) related this three performance levels with the size of damage and frequency of occurrence. This is shown in Figure 2. It can be appreciated that the skill based errors are the most frequent but purport less damage when comparing them with errors committed in the other two types.

The Figure 2 is useful to see that knowledge of procedures and principles of technology can be crucial for problem-solving, because they are the foundations on which the user will base the decision process.

Regarding the most common errors that a user commit in his or her interaction with technology, Dekker (2006) identified those contained in Table 1.

Roles	Errors related
Monitor	Lack of mode awareness
	Lack of awareness of any changes in the system
Collector of information	Overload of / get lost in information
	Increase workload processing information
Actuator	Not coordination off computing entries

Table 1: Roles of the user of technology and common errors (adapted from Dekker, 2006)

In addition, there are some particularities that technology has brought with, which in a certain level foster the occurrence of the mentioned errors:

1. Technology can make things invisible, or not appreciable by human beings. The presentation or interfaces can be fashionable but they can hide a lot complexity of information. The user can be aware of the status of the system, but not about the behaviour inside.[10]
2. The operators may switch to manage the computer interface instead of managing the situation. This is the same that Lutzhoft (2004) warned about when the tool becomes an end in itself, therefore it becomes inefficient.
3. The possible change of mode without alerting the operator.
4. Computers are not aware of the surrounding situation. The integrated system will perform the task according to the input parameters. However, if any changes occur in the environment, the integrated will not notice them by itself; the integrated system will need to be updated with the new parameters, otherwise they will not react accordingly to the new situation.

(Dekker, 2006).

3.3.- Management of Human Error in Shipping – FSA+HRA

Contrary to what was mentioned in Section 3.2, IMO has a definition of Human Error and accordingly has a procedure to assess the impact of Human Error in the industry. IMO defines Human Error as “a departure from acceptable or desirable practice on the part an individual or a group of individuals that can result in unacceptable or undesirable results”(IMO, 2007c, p. 21).

The definition does not show any consideration of context or situation; it was included here not only to show the difference of criteria that IMO has with other practitioners of Human Error studies, but also, to point out that this perception of

10 An example of this particularity was given in Section 2.4 p. 19

Human Error could be against the need to go into the HMI concept in depth.

The definition locates the individual at the centre of the potential unacceptable or undesirable practice and does not considers the possibility of having a technology centred designed, with which humans could not operate safely and efficiently.

IMO has included the analysis of Human Error in its methodology of risk assessment, called FSA and has been in used in IMO since 1997; recently, it was updated and condensed in one document (IMO, 2007c). Its purpose is to be used as the basic methodology when incorporating or updating regulations; currently, it is perceived as the normal methodology at the time of analysing different risk scenarios needed to be dealt with regulations.(Kristiansen, 2005).

The FSA involves 5 steps in a close-loop which are shown in Figure 3. The principle is that once the regulation has been created, its outcome needs to be verified taking the methodology again to Step 1. The five steps are:

1.- Hazard Identification (HAZID).

2.- Risk Analysis.

3.- Risk Control Options (RCOs).

4.- Cost Benefit Assessment (CBA).

5.- Recommendations for decision-making."

(IMO, 2007c, p. 5)

In this respect, hazardous industries have recognised that to improve the accuracy in any risk assessment, it is necessary to approach the human participation

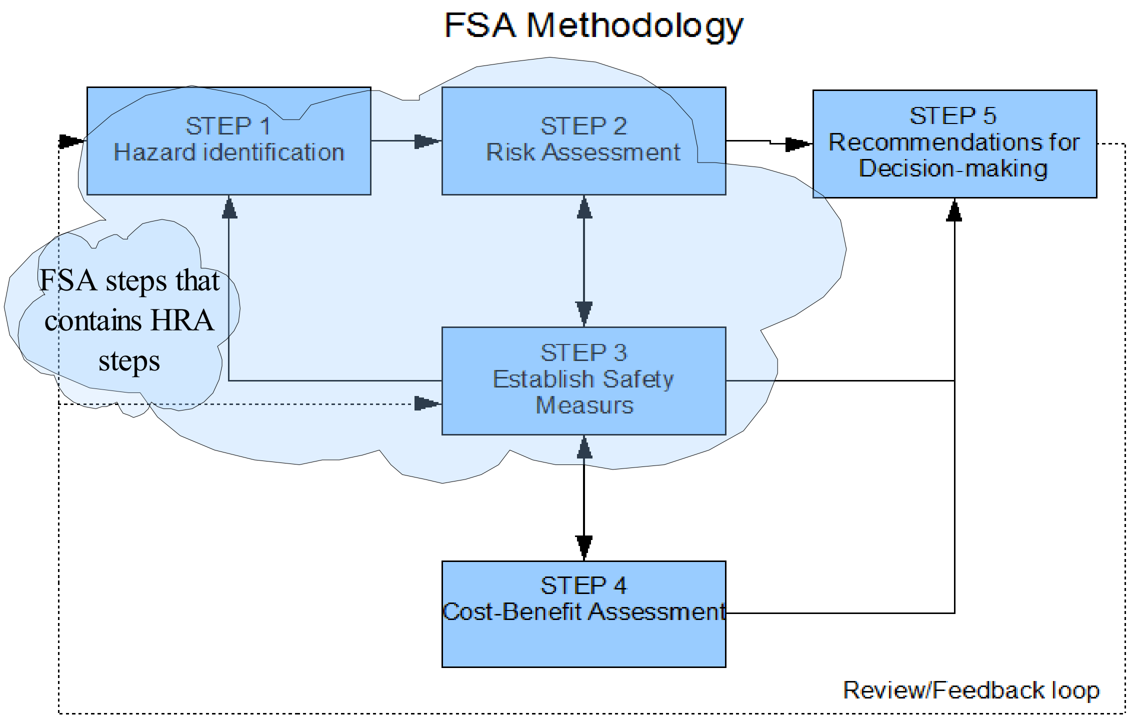


Figure 3: FSA Flow chart with indication of HRA steps (adapted from Kristiansen, 2005, p. 284)

to failures. Therefore, a methodology originated in the nuclear industry is utilized and is identified under the name HRA (Kristiansen, 2005).

This HRA methodology had to be adapted to the reality of the particular industry. For example, de nuclear industry does not incorporate human participation at early stages of the risk assessment due to its high level of automation where the participation of the human being is almost null (IMO, 2007c).

On the contrary, the maritime industry and the vessels in particular, the intervention of the Human Element in the system is more frequent and immediate. It can be appreciated in Figure 3 that the HRA plays a role on three of the five steps of the IMO FSA. This is due to the recognised "high-level task analysis" (IMO, 2007c, p. 20) needed in this particular industry.

Generally speaking the HRA is divided in five steps as follows:

1. Identification of key tasks.
2. Task analysis of key tasks.
3. Human error identification.
4. Human error analysis.
5. Human reliability quantification.

(IMO, 2007c, p. 20)

IMO states clearly that the HRA should not be overstressed and always has to be done in the same level of soundness as the corresponding FSA. Due to the limited data on the maritime field regarding Human Error, its determination depends much on expert opinions, however to carry on quantitative analysis HRA techniques are also considered.

Incidentally, there is a variety of techniques that can be applied to the HRA whose use will depend upon the availability of data, results expected, deepness of the analysis, and so on.(IMO, 2007c)

IMO normally uses two techniques:

- Technique of Human Error Rate Prediction (THERP);
- Human Error Assessment Reduction Technique (HEART).

(Kristiansen, 2005)

Both techniques are characterized by using a series of predetermined factors that contain quantified aspects affecting user's performance. THERP call its factors Performance Shaping Factors (PSF) and HEART call its factors Error Producing Conditions (EPC). They differ from each other, but the principle is the same: the consideration of predetermined factors that independently affects the performance of the user.

IMO considers THERP as the "best known and most"(Kristiansen, 2005, p. 332; IMO, 2007c, p. 34) used technique in analysing and quantifying Human Error probabilities. At the same time, it is recognised that is highly dependant on its Human Errors database, which is from the Nuclear industry. However, THERP can result in a high effort of analysis which can be more intensive than the effort required for the corresponding FSA. Nevertheless, its use is highly recommended due to be considered a good technique to analyse the RCOs and to evaluate systematically the role of Human Error.(IMO, 2007c)

For the case of HEART, IMO considers it simpler than THERP and with less necessity of having pre-saved data regarding Human Error. Also, IMO underlines the fact that HEART takes into consideration aspects of environment surrounding the tasks and Ergonomics (IMO, 2007c).

Kirwan (1997) has found that HEART does not perform well when assessing certain types of errors, such as undesired actions, simple slips, tasks needing decomposition and interdependent tasks. In addition, he identified that a certain level of inconsistency is allocated in how the General Error Probability is determined, which is a value allocated by the assessor to determine the probability of occurrence of certain error. Regarding the selection of EPCs, he also found certain inconsistency in this technique, mainly because the selection of EPC was related to the background or experience of the assessor.

HEART provides a fixed list of five contributions to reduce error when the FSA is in the stage of providing measures to minimize the identified risk,:

1. “Impaired system knowledge.
2. Response time shortage.
3. Poor or ambiguous system feedback
4. Significant judgement required of operator.
5. Level of alertness resulting from duties, ill health or the environment."

(IMO, 2007c, p. 25)

Regarding the Human Machine Interface, three of the contributions listed above are closely related to it, namely numbers 1, 3 and 4. The difficulty is how these five contributions are implemented after being accepted. For instance, are they applied on the seafarer improving his or her training and education to fight against the impaired system knowledge? Or, are they applied on designing a new system or improving the current one?

Kristiansen (2005) citing information from the IMO website, said that according to IMO, the maritime community is spending “80% of the available resources” (p. 295) to technical aspects, dedicating the “20%” (p. 295) rest to the Human Element. This distribution is not logical when looking at the data pointing out that 80% of the accidents are due to Human Error.

Regarding these two techniques which are considered to pertain to the first generation of HRA techniques, Kristiansen (2005) has indicated that there have been criticized by those who sustain the difficulty of determining Human Error based mainly in predetermined factors. Those criticisms comes particularly from ergonomics practitioners which perceive the impossibility of determine Human Error without a thorough consideration of context and situation (Kirwan, 1996).

Kristiansen (2005) provides a list of shortcomings found in this first generation techniques which is shown below:

- Questionable data used by these techniques to reflect real situations when assessing or predicting error probabilities.
- Lack of consistency regarding errors of commission.
- Inexistent proofs of accuracy of these techniques regarding their predictions.
- Arguable assumptions about human behaviour.
- Not enough treatment of PSF, particularly how this factors affect behaviour and performance.
- Static consideration of the situations.
- Mechanical decomposition of human actions.
- Uncertainty of the quantitative results.
- Not good to explain the cause of Human Errors.
- Lack of systematic task analysis.
- Lack of strategies to reduction of errors.

3.4.- Human error from other perspectives – CREAM & ATHEANA

Two other approaches to assess Human Error will be mentioned in this section that purport different foundations from THERP and HEART. They are identified as part of the second generation of HRA techniques and are the result from lessons learned from the formers techniques (Kristiansen, 2005).

To begin, Fujita & Hollnagel (2004) sustain that the use of PSF or EPC to establish the performance of the human being is not appropriate. On the contrary, they consider that it is necessary on every occasion to analyse the context which is what will be predominant to determine the Human Error.[11]

In this sense, Fujita & Hollnagel (2004) support this so called the second generation of HRA techniques, specially:

- Cognitive Reliability and Error Analysis Method (CREAM).
- A Technique for Human Element Analysis (ATHEANA)

Starting with CREAM, this methodology introduces what is called the 10 Common Performance Conditions (CPCs) which determine the context. The CPCs has to be considered interdependent and can increase or reduce the probability of error. They have to be applied regarding the level of control that the user has over the situation. Both, CPCs first and levels of controls later, will be listed below. The CPCs are:

1. adequacy of organisation,
2. working conditions,
3. adequacy of MMI and operational support,
4. availability of procedures/plans,

11 Section 4.2 regarding ISO 17894 shows that the same principle is sustained by ISO. ISO calls context as “context of use” and establishes what aspects of this context of use should be considered.

5. number of simultaneous goals,
6. available time,
7. time of day (circadian rhythm),
8. adequacy of training and experience,
9. crew collaboration quality,
10. communication efficiency".

(Fujita & Hollnagel, 2004, p. 146).

CREAM considers that in any situation, four could be the level of control, or modes, that the user can have over the situation, and these modes can perfectly fit in any analysis of accident situation, for example, in the maritime industry:

1. SCRAMBLED. In this mode the user has no possible control, no planning or preparation. Decision are totally by chance and actions normally are not related to the situation.
2. OPPORTUNISTIC. In this mode decisions are not sufficient. Success is not totally achieved. It happens when lack of competence or external factors among others, limit the possibility of a thorough planning process.
3. TACTIC. In this mode, actions respond to current situations. Planning has been done, however not completed. No foreseen situations are considered.
4. STRATEGIC. Thorough analysis and planning. Actions concurrent with planning and situations.

(Fujita & Hollnagel, 2004)

Following with ATHEANA, which is a technique applied on the nuclear industry and has as basic premise that it is necessary to contextualize potential situations in order to predict failures. It sustains that the PSFs in combination with the plant conditions (nuclear plant conditions) can lead to an error forcing situation, where the user can not review a miss diagnosis even when receiving contradictory information. (Powers, 1999)

- Chapter 4 - Regulatory status of the HMI regarding technology on the bridge

Safety Of Life At Sea 74 Convention and STCW 78 Convention amended in 1995, are the two IMO Conventions which deal with the incorporation of technology and training on the bridge. Currently, ISO has implemented mandatory standards to regulate the incorporation of technology on the bridge and its design.

Furthermore, there is a pile of IMO non-mandatory documents which are intended to be recommendations and guidelines in the aspect of dealing with new technology. Often, they are the predecessor of future mandatory regulations and indicate how the maritime community attention is shifting towards the issues.

4.1.- IMO Mandatory Regulations

First, the SOLAS 1974 Convention deals with bridge design and incorporation of technology in Chapter V. According to its Regulation 15, all the concerning matters relating to the incorporation of technology on the bridge should be oriented under the following fundamentals principles:

1. to ease the task;
2. to improve bridge resource management;
3. to ease the access to the necessary information;
4. "to indicate the operational status of automated components" (IMO, 2004a, p. 366);
5. to permit an efficient decision making process by the bridge team;
6. to facilitate the work on the bridge, preventing fatigue or interference with the task;
7. "to minimize and detect human error on the bridge". (IMO, 2004a, p. 366-367).

Above all, the principles indicate that technology should help the task of the OOW. However, there is no consideration to the HMI in this incorporation. All the principles are centred in what the technology should be capable of performing.

In addition, SOLAS 74 Convention contains in its Chapter 9 the Management for Safe Operations of the ships, which introduces the International Safety Management (ISM) Code to improve the Management of Safety at sea. ISM Code expresses in "broad terms" (IMO, 2002, p.5) procedures to enhance safety which are particularly allocated on the Company.

The Company has to set measures versus known risks and to develop a program to improve the skills of the personnel relating to safety operation. It also has to establish procedures for emergency preparedness, for training of new comers and maintenance of equipment to avoid "hazardous situations"(IMO, 2002, p. 11). There is no detail regarding consideration of HMI.

Second, the STCW 78 Convention as amended deals with the aspect of training certification and watch keeping of seafarer. It specifically remarks that the provisions are to be applied only to the training requirements described in the STCW 78 Convention as amended, consequently all other types of training are not bound by this Convention (IMO, 2001).

Moreover, as well as in the ISM Code, the STCW 78 Convention as amended dedicates particular attention to the training of new comers allocating this responsibility on the company. One particular requirement is to assure that seafarers are familiarized with "all ship arrangements, installations, equipment, procedures and ship characteristics that are relevant to their routine or emergency duties" (IMO, 2001, p. 33 Convention).

Likewise, regarding the general requirements to perform watch, the STCW Convention as amended requires "the familiarity of (the) officer with the ship's equipment, procedures and manoeuvring capability" (IMO, 2001, p. 152 Code) and the “operational status of bridge instrumentation and controls, including alarm systems” (IMO, 2001, p. 153 Code).

In addition, Section A-I/14 of the Code provides that the Company shall ensure by means of written procedures that fresh personnel has the chance to have a “reasonable opportunity to become familiar” (IMO, 2001, p. 24 STCW Code) with the equipment they are required to operate. However, there is no specification to what is the level of familiarization expected in the Convention to consider it satisfactory .

Finally, the STCW 78 as amended, addresses the minimum requirements that the deck personnel should comply with, which are further detailed in the Code to this Convention. Above all, there is no requirement regarding the knowledge about the specific equipment installed on board the specific vessel where the seafarer will operate, but familiarization.

4.2.- ISO 17894 – “Ships and marine technology — Computer applications — General principles for the development and use of programmable electronic systems in marine applications”

This document set down mandatory standards principles for marine electronic systems. It is a binding regulation that applies particularly to the producers of technology. This document refers to the marine electronic system as Programmable Electronic Systems (PES): “any shipboard system based on one or more sets of Programmable Electronic (PE) devices that are connected to input devices and output devices for the purposes of implementing control, safety or monitoring”(International Standard Organisation [ISO], 2005, p. 13).

The PES always has to interact in three levels; the first is with the user, the second is with the Equipment Under Control (EUC) and the third is with those external devices not belonging to the PES, but in a way provide or receive information to/from it (ISO, 2005).

The document mentions that any PES should follow the system engineering philosophy, by which the requirements of the system are collected from the users and other related operators with the goal of providing "operational capability" (ISO, 2005, p. 17), having in mind the complete life cycle of the PES. It is recognised that there will always be trade-off to manage between "competing factors of performance, risk and cost" (ISO, 2005, p. 17).

Furthermore, it addresses the fact that PES effectiveness will depend upon a thorough analysis of the "context of use" (ISO, 2005, p.2). Important aspects of the context of use are the user' characteristics, tasks expected to be performed, the software and hardware of the PES, the systems that interact with the PES, the environment on which the PES is expected to perform.

However, the consideration of the context of use turns out to be particularly difficult when acquiring Commercial-Off-the-Shelf (COTS) equipment. In this latter case, it is recommended to conduct a generic mode approach (ISO, 2005).

The context of use is required to be considered whenever a risk assessment on the incorporation of PES is carried out. In addition to the context of use, the impact on safety and performance of the ship that the PES will have has to be considered. The context of use and the impact on safety will be the two elements that will determine the soundness of the risk assessment (ISO, 2005).

This document provides a set of 20 principles under which any PES for marine purposes has to be designed and operated. Below are quoted seven of those principles that were identified as having close relation with the aspect of interface between the human beings and machines:

1. "The PES shall provide functions which meet user's needs" (p.7).
2. "Functions shall be appropriately allocated between users and PES" (p.7).
3. "The PES shall be tolerant of faults and input errors" (p. 23).
4. "The PES shall be acceptable to the user and support effective and efficient operation under specified conditions" (p. 26).

5. "The operation of the PES shall be consistent and shall correspond to user expectations of the underlying process" (p. 27).
6. "The interaction between the PES and the user shall be controllable by the user" (p. 28).
7. "Human-centred activities shall be employed throughout the life cycle" (p. 32).

Finally, this document stresses the use of the context of use as a basis in the design and development of PES. This context of use will be used with the characteristics of the future user and considering the task to be performed. This approach is more in line with what the second generation of HRA analysis techniques is saying, than with the THERP and HEART techniques.

4.3.- IMO non-mandatory regulations

The documents chosen here have as main subject INS and IBS. The purpose of checking this documentation is to see chronologically how the perception of the HMI interface has evolved since 1996 to 2007.

- 1996.- Resolution MSC.64(67) “Recommendations on performance standards for IBS”. This Resolution define IBS as: “a combination of systems which are interconnected in order to allow centralized access to sensor information or command/control from workstations, with the aim of increasing safe and efficient ship’s management by suitably qualified personnel“ (IMO, 1996, p. 3). The definition purport an implicit knowledge of the system by the personnel, and an improvement of safety. However, this improvement of safety will depend upon the proficiency of the operator interacting with the system.

  The document contains one reference to the HMI under the name of MMI, claiming that the MMI should be “easily understood and in a consistent style”(IMO, 1996, p. 5), there were no more explanation or detail. Also, it is mentioned that the IBS should be operable by a seafarer with the corresponding certifications. Going further, the Resolution details what should be the technical capabilities of the system, and little reference is made to the ergonomics and HMI.

- 1998.- Resolution MSC.86(70) "Annex 3 - Recommendations on performance standards for INS. This Resolution defines INS as: "a combination of systems that are interconnected to increase safe and efficient navigation by suitably qualified personnel" (IMO, 1998a, p. 9).

  Standards, functionalities and limitations of the system are described and there is space for ergonomics considerations. As specific guidance regarding the HMI, it says "integrated display and control functions should adopt a consistent HMI philosophy and implementation"(IMO, 1998a, p. 12), not giving any explanation about the mentioned philosophy.

  The Resolution does not consider the training that the users have to have to operate efficiently this equipment and to be prepared for failures.
- 1998 cont.- MSC Circ. 891 – "Guidelines for the on-board use and application of computers". These guidelines define Integrated System as: "A combination of Computer-Based Systems (CBS) which are interconnected in order to allow centralised access to sensor information and/or command/control" (IMO, 1998b, p. 2).

  In addition, it is specified that a CBS should be capable of performing the needed automated processes, accept the user input and give the pertinent information to the user. Furthermore, it is explicitly mentioned that a CBS should be feasible of being operated "without previous knowledge by the user"(IMO, 1998b, p. 5).

  Contrary to the two first Resolutions shown in this section, these guidelines dedicate special attention to the user interface where it is stated that they have to follow ergonomic criteria and be user-friendly. As a sample of that is the need for specific documentation in the form of operational guides that should be provided to the users.

Regarding the training, it is said that it has to be made looking forward to qualify personnel in the operation and maintenance of the "equipment in normal, abnormal and emergency situations" (IMO, 1998b, p. 9). However, it is contradictory that the CBS should be capable of being used by a user without previous knowledge, and later the document states that training is needed (IMO, 1998b).

- 2000.- MSC/Circ. 982 "Guidelines for ergonomic design of bridges equipment and layout"(IMO, 2000, p. 1). Its purpose was to provide support in the design of new bridges giving ergonomic requirements, and to be considered for further revision of Chapter V of SOLAS 74 Convention (IMO, 2000, p. 3).

  This circular basically deals with the layout of the bridge as well as distribution of the equipment. In a minor scale it approaches aspects of HMI as the display of information, the management of alarms, the controls operation and the mode awareness. It constitutes actually a reference document by further IMO documents in respect of ergonomics on the bridge and better utilization of bridge equipment by the users.

  One of the major points recommended to stress on is the consistency in procedures, displays, actions required by the operators, accessibility to controls. It is underlined that the system should provide unambiguous information.

  Also, using a coding that should be understandable for the user is considered. For that, the Guidelines call for the use of "familiar wording"(IMO, 2000, p. 23). The nature of shipping makes this familiarization hard, for saying the least, keeping in mind the variety of different cultures and nationalities that can operate on the bridge during the bridge lifetime (Squire, 2005).

Above all, the circular identifies seven workstations and each of them involves the corresponding functions and tasks. Those functions are:

- Workstation for navigating and manoeuvring.
- Workstation for monitoring.
- Workstation for manual steering, also called Helmsman's workstation.
- Workstation for docking on the wings.
- Workstation for planning and documentation.
- Workstation for safety.
- Workstation for communication.

(IMO, 2000, p. 3)

- 2003.- MSC/Circular1061 – “Guidance for the operational use of IBS”. These guidelines give a definition of mode awareness, situational awareness and failure analysis, in relation with the operation of the Integrated Bridge System. The document incorporates the need of adding a section on the Vessel Operating Manual specifically dedicated for IBS. This section is supposed to have summarized information of check lists and procedures to be carried out when alarms are triggered, among other types of information.

  Three different types of procedures are superficially described, identified as normal, abnormal and emergency procedures, which the seafarer has to be familiar with. Also, it is recommended the special care that has to be borne in mind when incorporating new technology. Regarding the training for those operators, the guidelines put on the Company's shoulders the responsibility of settling the knowledge and skill based training (IMO, 2003a).

- 2003 cont. - MSC Circ. 1091 – “Issues to be considered when introducing new technology on board ships”. The document, underlining that the introduction rate of computer assisted systems had been in an increasing trend, identified the need to address aspects of interrelation among users and technology. Among those aspects, the document highlights the need for designing computer assisted systems using a user centred philosophy, identifying the new training needs and adapting them to the education of the users.

Also, it recognizes the diversification of the technology applied on the bridges, which complicates more the situation at the time of identifying the training needs. Furthermore, the document underlines that training on technology is "not always achievable or possible" (IMO, 2003b, Annex p. 1). The author considers this statement particularly important because here IMO is saying that there are cases where seafarers are not familiar with the equipment they have to operate. There is nothing new in it, apart from the official recognition, which is later in the document reinforced with the characterization of the danger to safety that it signifies.

The Document claims for standardization at least for those most common operations; however, there is no mention to how IMO recommends to achieve this standardization.

Regarding training of users with technology, the document states that when dealing with bridges that are been refurbished, or bridges from new built ships, the crew normally is provided with a good level of familiarization with the equipment. Later on, that crew has to pass-on the information to the relieves in a non formalized process called "cascade training"(IMO, 2003b, Annex p. 2).

The document acknowledges that young generations of seafarers tend to be more keen and better than older generations in the use Information Technology (IT). However, the document underlines that this young generation tend to over rely on the systems.

Furthermore, the document uses the same terminology as Lutzhoft and Dekker (2000) giving the same perception about how automation has impacted the industry creating new paths of error and not eliminating tasks, but changing them.

Moreover, the document coincides with Bainbridge (1983) about the human limited capacity in monitoring automation systems, a problem that gets a more serious character when the automation system has been working without failures and is already installed when the users takes over.

Finally, the document shows as a fact that what technology has provided is an increase in information, which needs to be managed by the same user, and that clog of information constitutes a serious hazard.

- 2004.- MSC 78/11/3 - "Safety of Navigation. Bridge design, equipment and arrangements. Submitted by International Association of Classification Societies (IACS)". The document provides what IACS call Unified Interpretation (UI) of SOLAS 74 Convention Chapter V, and the "Standards for Bridge Design, Equipment Arrangement and Procedures (BDEAP)"(IMO, 2004b, Annex p. 8). The purpose of the BDEAP is to facilitate the safety operation on the bridge and to be used as a "check list" when designing or modernizing bridges.

  Specially, the document adds four more additional bridge functions to those mentioned in MSC/Circular 982: "extended communication functions, monitoring and control of ballasting and cargo operations, monitoring and control of machinery, monitoring and control of domestic systems"(IMO, 2004b, Annex p. 11); however, this document consider that the functions can be grouped in a way to reducing the workstations needed, which is not the same found in the MSC/Circular 982.

  Furthermore, the document provides a list of standard equipment, but it states clearly that it is "regarded as the responsibility of the owners and users that procedures, knowledge and training of the bridge personnel are related to the individual ship's bridge system”(IMO, 2004b, Annex p. 15). Going further, it states that the mentioned procedures should be specified in the Company and Ship Manual and in the ISM procedures as well.

Regarding the principles of design of navigational systems, it is specifically stated that they have to follow the ergonomic and human-machine interface criteria.

Finally, it was established that the requirements in the document contained are thought to be mandatory for IACS when acting as Recognized Organisation on behalf of the Flag State according to ISM Code.

- 2004 cont.- IMO Subcommittee on Standards of Training and Watch keeping (STW) 36/3/1 “ Validation of model training courses. Model Course-Operational use of IBS” . The aim of the course is to “provide(s) generic training in the use of IBS and INS”(IMO, 2005a, p. 8) to Masters and OOWs for vessels equipped with IBS or INS. The course has declared 7 objectives, among them is the understanding of HMI by the user when interacting with IBS. This course proposal suffered amendments (IMO, 2005a). However, the core of the course was not changed and is listed since 2006 in the Model Courses available (IMO, 2006).

The document starts acknowledging that the operation of an IBS “requires a level of knowledge beyond the normally given”(IMO, 2004c, p. 4) to an OOW. Moreover, the lack of standardization in this kind of equipment is specifically recognized and a set of recommendations are given to producers of this technology and to the shipping companies. These recommendations regards carefully the documentation that has to be given to the users by the manufacturers to ease the familiarization stage.

Giving particular attention to the lack of standardization, for the very first time in IMO Model Courses (IMO, 2004c), this course incorporates the need to familiarize the user with the particular equipment to be operated, after receiving this Model Course. This requirement intends to follow the spirit of the Section 6 of ISM Code (IMO, 2004c).

The course covers particularities such as types of IBS/INS, definitions, changes in the subsystems associated with IBS/INS, principles of using IBS/INS, mode awareness, failure analysis, and so on. It is scheduled to be delivered in 40 hours.

The inconvenience of this model course is the stress put on the use of Full Mission Simulator, an asset which is not available in all MET Institutions; therefore, making it difficult to be applicable throughout different Flag States. Almost half of the course is expected to be delivered using simulators.

- 2007.- NAV 53 / Inf. 4 – “Revision of performance standards for INS and IBS – Report of the correspondence group for INS and IBS - submitted by Germany”. The document underlines the need to assume INS as “one system” towards which other subsystems interact with. It gives reasons justifying the use of INS on board, as follows:

    1. INS supports safety of navigation by evaluating and combining data from several sources, consequently producing information.
    2. INS provides mode and situation awareness;
    3. "INS aims to be demonstrably suitable for the user and the given task in a particular context of use".
    4. “The INS aims to ensure that, by taking human factors[12] into

12 Attention should be given to how this document define Human Factor. The definition was quoted in Section 3.1.

consideration; the workload is kept within the capacity of the operator in order to enhance safe and expeditious navigation and to complement the mariner's capabilities, while at the same time to compensate for their limitations. “

(IMO, 2007a, Annex 1, p. 1)

The justifications chosen are closely related to the HMI. For example Number 1 speaks about the quality of the INS of evaluating inputs and combining them. Still it is not clear how INS can be able to do this without the participation of the user, who is at the end the one who makes the correct evaluation. Automated systems are abstracted from the environment and need the participation of the human to realize a close-loop evaluation with the input data and the desired outcome (Bainbridge, 1983; Reason, 1990; Lutzhoft, 2004).

Number 2, claims that INS improves situational awareness. In this regards, some accidents exist proving that due to over reliance on automation systems, the users tend to loose capability of situational awareness (Rowley et al, 2006).

Numbers 3 and 4 describe the importance of considering the user; however, other researches have shown that so far the design of these systems have been more technology centred (Rowley et al, 2006).

Furthermore, the document highlights the need for using principles of HMI in the overall design of the system. It is stressed that the design should be facilitating its understanding and operation by the user, underlining the control of erroneous inputs and assuring the quick and accurate interpretation of the system information output by the user.

Also, it gives special attention to the system documentation. This includes manuals containing description of function and failures, presentation of data, structure of redundancy, integrity monitoring, adjustment of parameters and installation with interconnection and power supply arrangements (IMO, 2007a, Annex 1, p.33).

In addition, the document specifies that a familiarization course for the specific INS installed on board has to be given to new operators. This provision is said to be under the spirit of the ISM Code. However, this familiarization course is required to be as short as possible, stressing the practical side. Adding that for a qualified user, 30 minutes should be enough to consider him or her familiar with the system.

- Chapter 5 - Bridge Team Management and Human Machine Interface

The technology applied on the bridge has to be used by the OOW acting with his or her team. The BTM becomes an important concept to define. Cases are found where the BTM are seriously affected by a lack of comprehension of the technology.

5.1.- Bridge Team Management

The efficiency of the watch on the bridge will depend upon the quality of the personnel and the technology applied on it (Swift,2004). Besides, the personnel has to know how to use the technology efficiently and safely. BTM is the term most commonly used to identify the operational performance of personnel and technology on the bridge.

IACS has provided, for the new revision of standards for IBS/INS, one long definition of BTM[13] from which some words have been highlighted to ease the understanding. The key elements of the IACS definition are manning the bridge according to the particular situation, the equipment fitted on the bridge and the familiarization of the crew members with such equipment. It is mentioned that those seafarers should be properly trained.

Consequently, the BTM for IACS is the crew trained and familiarized with the equipment and the equipment itself. In addition, the members of BTM has to know how to react in case of failure of such equipment (Swift, 2004).

Incidentally, another concept of BTM is related more exclusively to human

13"Safeguarding that the **composition** of the bridge team is **continuously appropriate** in relation to operational conditions **by manning** dedicated **workstations outfitted, arranged and located for performance** of specific functions and effective and **safe bridge** team **operations by properly trained and fit individuals**; **familiar with** instruments and **equipment** to be used and with their individual **duties and responsibility** as member of the current bridge team **and** with the **function**(s) to be performed at the individual workstations of the bridge team" (IMO, 2007b, p.8).

resources: “BTM refers to the management of the human resources (HR) available to the navigator -helmsman, lookout, engine room watch, etc.- and how to ensure that all members contribute to the goal of a safe and efficient voyage”(Bowditch, 2002, p. 364)

It does not mention a word about the equipment used by the OOW. Bowditch (2002), gives an even higher priority to the OOW on the bridge, considering that whatever technology fitted on the bridge, he or she has to be capable of using the technology effectively and safely.

Moreover, three aspects are recognised as having strong participation when it is tried to improve the human performance, and these are: “professional development, organisational structure and technology”(NRC, 1994, p. 6).

- Professional development is regarded as education and training of the seafarer, where also the training is included on his or her task and the related equipment.
- organisational structure is considered to be hierarchical distribution, as the distribution of responsibilities, functions and tasks on the bridge as well.
- Technology is regarded as the equipment the users have to operate on the execution of the task. It involves aspects of design of the equipment and aspects of interaction with the user.

(NRC, 1994)

These three aspects have to be used in conjunction and updated with each other. For example, while state-of-the-art technology can provides modern means to carry out the task on the bridge, it will not be able to do so without the specific training in relation to its operation by those operators. Also, since technology changes the execution of the task, the structure of the team organisation has to be reviewed (NRC, 1994).

Following, there are two accident where a problem of knowledge of the technology by the BTM were verified. These two examples occurred two years ago; fortunately, the outcomes of both accidents did not involve any loss of life or pollution; however, they constitute an indication of one very serious hazard.

5.2.- Heeling Accident on M/V Crown Princess (18 July 2006)

The Crown Princess is a passenger vessel of 113,561 gt, with 19 decks, 289 metres in length and 48.5 metres wide. It was finished in March and christened in June 2006. The Accident Report does not give exact information of the date of being appointed for duty. The accident occurred in July of the same year which means that the crew had not more than 4 months operating on board this vessel (NTSB, 2008).

Figure 4: Crown Princess

The vessel was considered to be appropriately manned and the crew well rested. The Crown Princess had just left Port Canaveral in Florida, United States, with 3,285 passengers and 1,260 crew members, for its next destination, New York. On the bridge remained the Captain, Staff Captain, Second Officer, two Fourth Officers and two helmsmen. The Crown Princess was equipped with a NACOS 65-5 automated INS, which was considered the latest version made by Sam Electronics at the time it was installed aboard (NTSB, 2008).

Under the Captain's orders, the vessel was proceeding in automated control at 20 knots with the speed control passed to the engine room. The Captain realised that the vessel started to perform an undemanded turning to port. Consequently and agreeing with the advice of the Staff Captain, the Captain ordered to increase the Rudder Limit[14] from 5 degrees to 10 degrees intending to control this turning to port.

14 The Rudder Limit is a parameter that can be selected by the OOW which limit the maximum angle of the Rudder to both sides

(NTSB, 2008).

Without solving the problem, the Captain and Staff Captain left the bridge, handing over the conn to the Second Officer. The Second Officer was reported on duty on board the Crown Princess on July 2006. He spent 5 days familiarizing with the ship and then started to perform duties as OOW. Having taking over the conn, he realized that the vessel kept the tendency of turning to port. Then, he tried to correct this trend switching from automated control to manual control and steering the wheel by himself (NTSB, 2008).

Unfortunately, the Second Officer not receiving the feedback he expected in the time he expected, he moved the wheel many times to both sides in maximum angles. The vessel was proceeding at 20 knots. A heeling to starboard increased up to 24 degrees. This unexpected heeling angle caught crew and passengers unprepared and as a final result almost 300 people were injured, from which 14 were considered as serious injuries (United States' Code of Federal Regulations as cited by NTSB, 2008). The relief Captain was the first to arrive to the bridge and ordered to reduce speed, which almost immediately solved the heeling angle and the vessel became upright again. (NTSB, 2008)

5.2.1.- HMI aspects

1. TRAINING. The Second Officer' previous vessel was the Diamond Princess which was equipped with a NACOS INS system, similar to that of the Crown Princess. He had been on board the Diamond Princess for almost three weeks. (NTSB, 2008)

   According to Lutzhoft and Dekker (2002) users are provided with mental models at the time of interacting with technology. Those mental models are moulded by “expectations and knowledge, training and education, and actual experience of using (the) system”(Lutzhoft & Dekker, 2002, p. 88) on different real occasions.

The Second Officer declared in the accident investigation that he was not familiar with the use of the NACOS INS 65-5 in automated control mode because the former vessel was used in Alaskan waters where, due to icy waters, the normal practice was to sail under manual control (NTSB,2008).

Furthermore, he had had a three days course in NACOS in 2004. He was considered to have had all the requirements satisfied at the time of taking over the conn.

2. FAMILIARIZATION. It cannot be said that the Second Officer was unfamiliar with the NACOS INS; however, this familiarization was not enough to help him in managing the situation. His 5 days of familiarization with the vessel were registered, which can be considered to be in agreement with the STCW and the ISM Code.

3. CONTROL OF THE SITUATION. Errors are originated from the fact that the user of the technology or machinery, having faced a new situation with no information or preparation available, he or she has no appropriate reaction, consequently an error occurs (Reason, 1990). In this case the Second Officer did not understand why the vessel was turning to port. In an intention to solve the problem, he overrode the automation system and tried to counter react governing the vessel manually.

   Remembering Fujita & Hollnagel (2004) about the levels of control that a user has over a situation, the Second Officer lost total control of the situation (SCRAMBLED[15]). In this regards it was shown in practice what Lutzhoft said about the fact that seafarers do not use technology in emergency situations.

4. KNOWLEDGE OF THE TECHNOLOGY. The NACOS 65-5 allowed the users to set determined parameters depending upon the situation. Those parameters are the Rudder Limit, the Rudder Economy and the Course Limit.

15 See Section 3.4

The Rudder Economy could be chosen in a range of 10 different levels and level 5 was the selected level when the accident happened. According to the producer of that technology, this level of Rudder Economy was thought to be used in bad weather (NTSB, 2008). As the level was increasing in number, the aim was to provide more flexibility to the rudder position accordingly to the rough weather.

In the report it was established that the weather conditions were calm. This actual setting of the Rudder Economy was not in the awareness of the Second Officer (NTSB,2008).

Also, the system had three different modes to carry out the navigation: Heading Mode, Course Mode and Track Mode. Heading Mode was selected at the time of the accident, which meant that the autopilot had to follow the course established using mainly the Gyrocompass signal (NTSB,2008).

Sam Electronics, requested by the NTSB, conducted an investigation about the accident and concluded that "an improper Rudder Economy setting and Rudder Limit setting can lead to a non proper function of steering in Heading Mode for this ship's speed of 18 to 20 knots together with the measured water depth" (NTSB, p. 20, 2008).

It would have been better to have this information prior the accident.

5. OVER RELIANCE ON TECHNOLOGY. The Captain having perceived an unexpected evolution of the vessel, did hand over the watch to the Second Officer and left the bridge. According to the Accident Report, the Captain expected that after having selected the new Rudder Limit, the INS would need some time and would stabilize the course. He did not give any particular order to the Second Officer in this regard (NTSB,2008).

   According to the Accident Report, the Company had a policy regarding when the Captain should leave the bridge, stating that the navigational situation should be clear. Obviously, the Captain did not appraise any potential hazard when he left the bridge.

6. ROLES INTERACTING WITH TECHNOLOGY. According to Lutzhoft (2004), one of the roles that a human being has to perform when interacting with technology is monitoring, which is hampered by two main aspects. Users tend to monitor less when the system is already installed and when the system has been working without failures (Lutzhoft, 2004; Bainbridge, 1983). The main reason is because they tend to over rely on the system. So did the Captain as he declared on the Investigation Report.

7. DIFFICULTIES TO UNDERSTAND WHAT WAS HAPPENNING. In the Report Investigation the lack of recognition of the shallow water effects is mentioned. The Captain ordered to increase speed to 20 knots, and according to the investigation there was not sufficient depth to avoid the shallow water effect. Since the vessel was being steered automatically, the OOW did not immediately recognize the loss of manoeuvring capability. This situation was not recognize either by the NACOS INS. Electronic systems are not aware of the surrounding situation and not embedded in the environment; this is why they need the human intervention (Dekker. 2006; Lutzhoft, 2004).

8. THE LACK OF HMI AS A CAUSE. The causes of this accident found by NTSB (2008) can be summarized as:

    - Primary cause: incorrect wheel commands by the 2nd Officer.
    - Contributory Cause: incorrect inputs to the system by Captain and Staff Captain.
    - Contributory Cause: insufficient training in INS operation.

    However, taking a look at the complete report the lack of relationship between the OOW and the INS is notorious. Looking at what happened from hindsight he made an incorrect decision; however, it was not what he intended to do. For him, there was something that he did not understand, and he reacted in the way he had learnt.

This accident could have been much more serious, which luckily it was not. The vessel was according to regulations, the ship was just brand new and the crew was all certified accordingly.

5.3.- Allision of Chemical/Oil Tanker Vessel Prospero (10 December 2006)

The Tanker Vessel Prospero was built in 2000, with 11,973 gt, capacity of 16,800 dwt and a length of 145,7 metres. It was provided with a podded propulsion drive system called Siemens-Schottel Propulsor (SSP) that could be operated from

Figure 5: Tanker Vessel Prospero

the bridge and engine room (MAIB & Swedish Accident Investigation Board, 2007).

Originally, it was possible to rotate the SSP 360 degrees. Nevertheless, at the time of the accident could only be turned 180 degrees to both sides. This limitation was known by the corresponding Classification Society, which had delivered a Condition of Class. The Master was also aware of this limitation (MAIB & Swedish Accident Investigation Board, 2007).

At 00:35 hours the vessel was intending to moor its port side alongside the Milford Haven's jetty (UK) to load cargo. The vessel was almost empty, having only an over-carried cargo of 220 tons of kerosene. The BTM was composed by the Master and the pilot. For unknown reasons, the Master did not inform the pilot about the limitation on the Pod, and since this particular vessel was allowed to enter to Milford Haven without tugs, so it did and the pilot agreed (MAIB & Swedish Accident Investigation Board, 2007).

When the vessel was near to moor alongside the jetty, the Master switched the engine control from the central console to the port console. The vessel's speed was around 1 knot and the Master intended to increase the speed a little in order to keep manoeuvring capability. Suddenly, the lever moved undemanded increasing the engine power to 70%. From this moment onwards, neither the Master nor the pilot could respond to this unexpected event successfully (MAIB & Swedish Accident Investigation Board, 2007).

At the end, the Propulsion Control System performed some activities which were not understood by any of both officers; resulting in two allision with the jetty, one going ahead and one going astern, with structural damages to the vessel, pier and jetty. Luckily enough, there was no personnel injured or loss of life and the vessel was almost empty of cargo. No oil spill was registered.

5.3.1.- HMI aspects

1. TRAINING. The Master had been appointed on board in September 2006, three months before the accident happened. His certificates were up to date and he was considered to be an experienced Master. The Prospero Company has a working system for its crew one month on and one month off. This routine meant that the Master was doing his second trip as a Master on board the Prospero. It was found that neither the Master nor the engineering officers had had training in SSP.

   Furthermore, the accident report identified as one safety issue that the training requirements contained in STCW 78 as amended for engineer personnel were “inadequate for this type of complex plant”(MAIB & Swedish Accident Investigation Board, 2007, p. 58). The relevance of this finding for the present research is considered twofold. One is that the engineering department is part of the Human Resources of the BTM (Bowditch, 2002), because their appropriate qualifications are regarded as relevant. Second, it pointed out that the requirements of STCW did not satisfy the current reality of technology. In this case, the technology is at least 10 years old, and the crew was not prepared to deal with it.

2. TECHNOLOGY DEGRADATION. The Master of Prospero could have been victim of a latent error in this case originated from “faulty maintenance and bad management decisions”(Reason, 1990, p. 173). There is no mention to whether it had been a risk assessment when the system got deteriorated due to the faulty Gauss transmitter, which limited its original capability of turning 360 degrees. The decision was to continue trading with the ship, and in this way the risk of having an accident was taken.

   Hollnagel (2007) says that sometimes, as in case of aviation, the risk of falling down an air plane can be eliminated by cancelling the flight, but this decision is against the proper nature of the industry; therefore, the decision of stopping the flight is not viable, consequently other approaches to reduce the risk of falling down the air plane are taken.

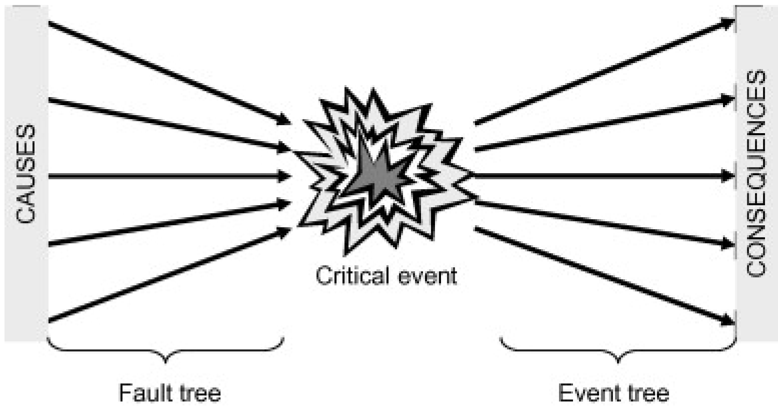


Figure 6: The risk Bowtie model (Hollnagel, 2007, p. 223)

In the case of Prospero and looking at it from hindsight, symptoms indicating problems with the SSP were not considered as samples of potential failures (MAIB & Swedish Accident Investigation Board, 2007).

Using the Bowtie model of causes for an accident to happen (Figure 6), it seems that the company disregarded some indication that could have resulted in the accident; the system had had similar failures before, new personnel was appointed on board and no training in reversionary modes of the SSP was given to the new Master or engineer department, the Master did not asked for tugs to help in the manoeuvre.

As is cited by Hollnagel (2007), an accident can happen due to an undesired event originated by certain causes, and due to a faulty use of the barriers (Reason, 1990). Barriers can be classified in functional, incorporeal, physical and symbolic (Hollnagel, 2007). In the case of the Prospero, it seems that no effective use of any barrier was even tried to perform. The alarm was not acknowledged (symbolic), the use of tugs was not considered (physical), the reversionary mode was not understood by the user (functional) and there was no procedure written in the Safety Manual of the Company to deal with this kind of situation(incorporeal) (MAIB & Swedish Accident Investigation Board, 2007; Hollnagel, 2007).

3. FAMILIARIZATION. It was found by the accident investigation that the personnel considered the SSP very reliable and comfortable to use. The crew was familiar with operating the controls, but not with reversionary modes. Consequently, the Master did not realize that the system triggered a reversionary mode because of a failure on the primary propulsion system. Furthermore, the Master did not notice an alarm indicating a failure on the primary propulsion system (MAIB & Swedish Accident Investigation Board, 2007).

4. HMI DESIGN. The accident investigation found deficiencies in the design of alarms. The Master did not acknowledge the alarm indicating the failure of the primary propulsion system because he did not see it. The reason found was that the alarm light was dimmed together with the rest of the lightnings. Also, the volume of the audible alarm was not enough to overcome the environmental noise.

   The investigation report indicated that, at the time of constructing the Prospero, the corresponding Classification Society did not have a policy regarding the HMI concept. Furthermore, there was no requirement regarding the documentation to be submitted by the technology producer ((MAIB & Swedish Accident Investigation Board, 2007). This left Prospero in the year 2000 with a complex propulsion system without an assessment on how the interaction between the human being and technology would be with this system.

5. CONTROL OF THE SITUATION. Not understanding the situation, the Master literally started to fight against the control levers. He tried unsuccessfully to reduce the engine power by pushing the lever back. After a while, the engine power was reduced to zero without intervention of the

Master. Nevertheless, it increased power again to 70% after a few moments. Just after the second collision going astern, the Master passed the control of SSP to the Engine room and back to the bridge; then, the operation became normally again (MAIB & Swedish Accident Investigation Board, 2007).

During the reversionary mode, there was a complete lack of awareness in what was happening by the side of the Master. (MAIB & Swedish Accident Investigation Board, 2007).

- Chapter 6 - Conclusions and Recommendations

6.1.- Conclusions

This investigation has concluded that it does exist a gap between technology on the bridge and the BTM, which affects the safety operation of the latter. The gap has its routes in problems of design and incorporation of technology without consideration of the user's characteristics and expectations, and on the training that the user should receive previously being appointed to operate that technology.

However, it could not be proved whether the mentioned gap is in an increasing trend or not. Indeed, it should be said that the gap is in the awareness of the maritime community which is trying to convince the stakeholders of its existence and to react accordingly.

In the last three years, Quality organisations and Classification Societies are establishing mandatory regulations regarding the introduction of ergonomics design and HMI when designing and incorporating technology on bridges. IMO, mainly through non-mandatory documents, has shown in latest times its concern in the issue of HMI trying to attract attention in this matter.

Following are subsequent detailed conclusions resulted from this investigation:

1) Technology has to have a pre-designed interface created on purpose for the future user. In the maritime industry, this aspect is particularly difficult due to the very nature of multinational, multicultural and multilingual industry, which signifies that people with strong differences among each other can operate the equipment.

2) IMO considers HMI as a technical issue, an intrinsic aspect of technology design. On the other hand, designers tend to consider wrong actions committed by human beings as non-technical aspects of technology. These

wrong actions can be the outcome of a variety of factors, among them it could be a wrong designed HMI and an improper education of the user on the use of the technology.

3) The introduction of users' characteristics and expectations, as well as ergonomic principles, did not take place in the design of INS and IBS until the end of the 1990s, which affected the design of the HMI. The design of the technology provided on-board was more technology centred, provided with some interfaces which in many cases did not satisfy the user's expectations. Consequently, technology was not used according to its design.

4) It does exist a different philosophy between designers and users when dealing with technology. This difference obliges the user to adapt to a tool designed by a person with a different perspective about what technology should be able to do and how. This drawback can be reduced by using ergonomics.

5) In the maritime industry, there is no standard mandatory provision about what documentation and training should the technology producer deliver to the user.

6) Users' expectations are influenced by the perception users have about technology. There is still the same scary perception about technology which lead to an improper use of it.

7) Technology today is less prone to be used under manual modes, which purport a further hazard when the users prefer to operate it manually.

8) Users need to have the knowledge of technology organized which should include more than normal simple operation. This is not the normal practice in shipping.

9) Automation hinder the opportunities of practicing the user's skill, providing a long time of low workload, which lets the user to be relaxed. This situation tends to delay or cancel the reaction of the user in an emergency.

10) Technology has introduced more layers between the user and the final equipment which performs the task, which in turn splits the user more from what is happening. Users can induce unintentional errors whose consequences will be delayed in time, the so-called latent errors.

11) The Human Factors is a concept that leads to different interpretations, therefore it has served as a term where many different things can fit into. IMO particularly identifies as the Human Factor as the person plus the training required by the organisation. The problem with this perception related to the HMI is that the training on the technology does not constitute today a requirement in any convention, besides familiarization.

12) The concept of HMI involves the interaction of human beings with technology to perform a task. For that, HMI needs a clear understanding of the Human Factor to be designed accordingly. If there is confusion or ambiguousness in the terminology, a misled address to the HMI can be executed.

13) A general trend was found of attributing every wrong happening with technology to wrong action committed by humans, assuming human beings to be less reliable than technology. Moreover, there is a proved tendency to incorporate more technology in order to deal with the unreliability of the human beings. However, INS and IBS systems do need the presence of human beings to operate.

14) Human Error is generally considered to be a complex issue, where aspects of human beings, situation and environment play important roles; however, IMO has a definition of Human Error which does not specify what are the acceptable practices or the undesirable results.

15) IMO incorporates the HRA inside the FSA in order to assess the participation of human aspects on the overall risk, but stressing that this part of the Safety

Assessment should not be overstressed. Furthermore, data has indicated that the major effort of resources in the maritime industry is being done more in technical aspects than on the human side. It seems as to be an intention of considering the human being in the industry but at the same time not much effort is allocated to understand it and improve its quality.

16) The techniques used in IMO to assess human reliability are being put aside in other industries and succeeded by a second generation of HRA techniques. These techniques are strongly criticized by ergonomic practitioners. The second generation of HRA techniques gives to the context of use of the technology the principal factor that determines the occurrence of error.

17) It was found that the requirements contained in SOLAS 74 regarding the incorporation of technology on the bridge, are centralized in what technology should be able to do, which is generally speaking, easing the task of the Bridge Team Management. However, there is no consideration of the user's characteristics and expectations. Therefore, it should be argued how technology can ease the task of someone who perhaps does not understand that technology.

18) The ISM Code and STCW 78 as amended, include the aspect of training with technology within the broad term familiarization with the equipment, not stating clearly how this familiarization should be done and verified. The responsibility of the familiarization is assigned to the shipping companies.

19) In 2003, IMO started to include training considerations in its non-binding regulations allocating the responsibility of that on the shipping companies. In this regard, IMO has acknowledged the difficulties occurring when intending to train in the new technology, recognising the existence of situations where users are not provided with any training on the technology they have to operate.

20) In 2005, IMO recognising that special knowledge is required by the OOW to operate IBS/INS, validated a model course for IBS/INS. This course intends to provide foundations of these systems. However, it also needs to be supported by a posteriori familiarization of the specific equipment, taking into account the lack of standardization in design.

21) Last year, a proposal was submitted to revise the INS/IBS performance standards to be included in further revisions to the SOLAS 74 Convention. The document underlines the advantages of using INS/IBS. However, these systems still need an efficient interaction with the OOW in order to really show those advantages. Still how to educate and train the OOW on the new technology remain to be regulated.

22) It was found that the concept of HMI was not considered by some stakeholders in the maritime industry at the beginning of this decade. Vessels built at that time are still operating.

23) The BTM performance depends upon how the OOW operates the technology applied. Some examples are showing that there is a real lack of knowledge by the OOW and Masters regarding the features of technology. Still, it can not be said that this shortfall has caused serious damage; however, the case of Crown Princess shows a clear example of the hazard that the lack of knowledge of technology from the users signifies.

6.2.- Recommendations

- To address appropriately the problem of the gap between technology and users, it would be highly necessary to review certain fundamentals concepts such as Human Factor, Human Element and Human Error. For that, it is recommended that experience from other hazardous industries be taken. In this regard, the Appendix A with the adaptation of the check list used in the petrochemical industry, provided to the MEPC in 2005, provides a good guideline to follow.

- Since the trend of incorporating technology will not stop but otherwise, it is necessary to train the OOW as soon as possible. It is recommended that the Model Course regarding operation of IBS/INS be included as part of the mandatory requirement in the STCW 78 as amended for Masters and OOW. However, IMO should have to consider how to manage the simulators requirements for this course. Simulators are assets that are not available by all Flag States and represent a high investments for MET institutions.
- It is also recommended that IMO reviews and clarifies the term familiarization. Familiarization with technology is a very broad term. There are cases showing personnel that had had familiarization time but did not know how to use the technology. So far the familiarization is allocated as a Company responsibility, so it is recommended that it should be kept like this, but a way of controlling this aspect should be found.
- The SOLAS 74 Convention is needed for an update regarding the current reality of technology on the bridge. It is recommended that a revision of Chapter V of SOLAS be carried out considering the new revision of performance standards for IBS and INS, which also include more consideration to the user in the design of this technology.

REFERENCES

Bainbridge, L. (1983). Ironies of Automation. . Retrieved May 3, 2008, from the World Wide Web: http://www.bainbrdg.demon.co.uk/Papers/Ironies.html.

Barnett, M. (2007). Mitigating human error in the use of automated shipboard systems. *Alert - The International Maritime Human Element Bulletin*, (15). Retrieved June 9, 2008, from http://www.he-alert.org/documents/bulletin/Alert!_15.pdf.

Bernard, A., & Hassan, R. (2002). Working situation model for safety integration during design phase. *CIRP Annals - Manufacturing Technology*, *51*(1), 119-122. Retrieved June 5, 2008, from the World Wide Web: www.sciencedirect.com

Bowditch, N. (2002). Chapter 25. Navigation processes. In *American Practical Navigator* (pp. 363-373). Bethesda, Maryland: National Imagery and Mapping Agency. Retrieved March 31, 2008, from the World Wide Web:

http://www.nga.mil/portal/site/maritime.

Dekker, S. (2006). *The field guide to understanding human error.* Aldershot England ;Burlington VT: Ashgate.

Earthy, J., & Sherwood, B. (2007, January 3). *Design for the human factor. The move to goal-based rules*. Retrieved April 30, 2008, from the World Wide Web:

http://www.he-alert.com/documents/published/he00570.pdf.

European Commission-Transport RTD Programme. (2001, August 14). *Human factors - Paper 8 of 10 - Thematic synthesis of transport research results*. Retrieved June 3, 2008, from the World Wide Web: http://www.transport-research.info/Upload/Documents/200408/20040809_154650_30174_human_factors.pdf.

Fujita, Y., & Hollnagel, E. (2004). Failures without errors: quantification of context in HRA. *Reliability Engineering and System Safety*, *83*, 145-151. Retrieved June 1, 2008 from the World Wide Web: www.sciencedirect.com.

Graveson, A. (2005). *Human factors and safety at sea*. Retrieved May 14, 2008, from the World Wide Web:

http://www.he-alert.com/documents/published/he00190.pdf.

Helm, J. (2008). Bridge design. Ghost Ship to Port! *Nonstop*, *2*, 45-46.

Hetherington, C., Flin, R., & Mearns, K. (2006). Safety in shipping: The human element. *Journal of Safety Research*, *37*, 401-411. Retrieved June 10, 2008 from the World Wide Web: www.sciencedirect.com.

Hollnagel, E. (2007). Risk + barriers = safety? *Safety Science*, *46*, 221 - 229. Retrieved from the World Wide Web: www.sciencedirect.com

International Maritime organisation (IMO). (2004a). *SOLAS, consolidated edition, 2004 :* London :: International Maritime organisation,

International Maritime organisation(IMO). (1996, December 4). *Adoption of new and amended performance standards. Annex I - Recommendation on performance standards for integrated bridce systems (IBS)* (MSC.64(67)). London: Maritime Safety Committee.

International Maritime organisation (2001). *STCW 95 : International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978, as amended in 1995 (STCW Convention) ... and Seafarer's Training, Certification, and Watchkeeping Code (STCW Code), including resolution 2 of the 1995 STCW Conference*. In . London: International Maritime organisation.

International Maritime organisation(IMO). (1998a, December 8). *Adoption of new and amended performance standards for navigational equipment. Annex 3 Recommendation on performance standards for an integrated Navigation*

System (INS) (MSC.86(70)). London: Maritime Safety Committee

International Maritime organisation (IMO). (1998b, December 21). Guidelines for the on-board use and application of computers (MSC/Circ. 891). London: Maritime Safety Committee.

International Maritime organisation(IMO). (1998c, November 20). *Interim Guidelines for the Application of Human Element Analysing process (HEAP) to the IMO rule-making process* (MSC/Circ.878 - MEPC/Circ.346). London: International Maritime organisation.

International Maritime organisation(IMO). (2000, December 20). *Guidelines on ergonomic criteria for bridge equipment and layout. . International Maritime organisation* (MSC/Circ. 982). London: Maritime Safety Committee.

International Maritime organisation. (2002). *International safety management code : ISM code and revised guidelines on the implementation of the ISM code by administrations*. London: International Maritime organisation.

International Maritime organisation(IMO). (2003a, January 6). *Guidance for the operational use of Integrated Bridge Systems (IBS)* (MSC/Circ. 1061). London: Maritime Safety Committee.

International Maritime organisation (IMO). (2003b, June 6). *Issues to be considered when introducing new technology on board ship* (MSC/Circ.1091). London: Maritime Safety Committee.

International Maritime organisation(IMO). (2003c, November 27). *Human element vision, principles and goals for the organisation* (Resolution A.947(23)). London: International Maritime organisation.

International Maritime organisation(IMO). (2004b, February 6). *Safety of Navigation. Bridge design, Equipment and Arrangements. Submitted by the International Association of Classification Societies (IACS)* (MSC 78/11/3). London: International Association of Classification Societies.

International Maritime organisation (IMO). (2004c, August 12). *Validation of model Training Courses. Model Course - Operational use of IBS* (STW 36/3/1). London: Maritime Safety Committee.

International Maritime organisation (IMO). (2005a, January 12). - *Validation of Model Training Courses - Report of the Drafting Group* (STW 36/WP.4). London: Subcommittee on Standard of Training and Watchkeeping.

International Maritime organisation(IMO). (2005b, May 9). *Future Role of formal safety assessment and human element issues. Human Element Strategy. Submitted by the United States* (MEPC 53/19/3). London: United States Delegation to MEPC.

International Maritime organisation (IMO). (2006, July 6). *Validation of model training courses - Report on the model course programme* (STW 38/3). London: Subcommittee on Standard of Training and Watchkeeping.

International Maritime organisation(IMO). (2007a, April 19). *Revision of performance standards for INS and IBS. Report of the correspondence Group for INS and IBS. Submitted by Germany* (NAV 53/Inf. 4) . London: Germany Delegation to NAV.

International Maritime organisation(IMO). (2007b, April 20). *Revision of the performance standards for INS and IBS. Recommendation for application of SOLAS regulation V/15 for new-buildings. Submitted by the IACS* (NAV 53/Inf. 5). London: IACS delegation to NAV.

International Maritime organisation (IMO). (2007c, May 14). *Consolidated text of the Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process (MSC/Circ. 1023-MEPC/Circ. 392)* (MSC 83/Inf.2). London: Maritime Safety Committee.

International Standard Organisation (ISO). (2005). *ISO 17894 - Ships and marine technology-Computer applications- General principles for the development and* *use of programmable electronic systems in marine applications*. Geneva.

Jiménez, R. (2007). Automation, STCW and electronics officers. *Alert - The International Maritime Human Element Bulletin*, (15), 7.

Kirwan, B. (1996). The validation of three Human Reliability Quantification techiques - THERP, HEART and JHEDI: Part 1 - technique descriptions and validation issues. *Applied Ergonomics*, *27*(6), 359 - 373. Retrieved July 1, 2008, from the World Wide Web: www.sciencedirect.com.

Kirwan, B. (1997). The validation of three Human Reliability Quantification techniques - THERP, HEART and JHEDI: Part III - Practical aspects of the usage of the techniques. *Applied Ergonomics*, *28*(1), 27 - 39. Retrieved July 1, 2008, from the World Wide Web: www.sciencedirect.com.

Kristiansen, S. (2005). *Maritime transportation : safety management and risk analysis*. Oxford; Burlington, Mass.: Elsevier Butterworth-Heinemann.

Lutzhoft, M. & Dekker, S. (2002). On your watch: Automation on the Bridge. *The Journal of Navigation*, *55*, 83-96. Retrieved May 2, 2008, from the World Wide Web:

http://journals.cambridge.org/download.php?file=%2FNAV
%2FNAV55_01%2FS0373463301001588a.pdf&code=3c729e9e9143d9e3d36ee
bf438633b36

Lutzhoft, M. (2004). *"The technology is great when it works". Maritime Technology and Human Integration on the Ship's Bridge*. University of Linköping. Sweden. Retrieved May 22, 2008, from the World Wide Web: http://www.ikp.liu.se/usr/marlu/IKP-Diss907.pdf.

Marine Accident Investigation Branch. (2002). *Report on the investigation of the parting of the mooring line between the Tetney buoy and the North Sea shuttle tanker Randgrid, resulting in discharge 0f 12 tonnes of crude oil into the Humber Estuary on 20 December 2000*. Southampton - United Kingdom.

Retrieved June 1, 2008, from the World Wide Web:

http://www.maib.gov.uk/cms_resources/randgrid.pdf.

Marine Accident Investigation Branch, & Swedish Accident Investigation Board. (2007). *Report on the investigation of the loss of control of product tanker Prospero an her subsequent contact with a jetty at the SemLogistics terminal, Milford Haven / 10 December 2006.* Retrieved June 6, 2008, from the World Wide Web: http://www.maib.gov.uk/cms_resources/Prospero_report.pdf.

Marine Accident Investigation Branch. (2007). Case 9 - But We've Always done it that way. *Safety Digest*, *1*. Retrieved May 21, 2008, from the World Wide Web: http://www.maib.gov.uk/cms_resources/SD%5F1%5F2007%5FPART %5F1%2Epdf.

Muirhead, P. (1992). One-man bridge systems. Operational aspects and future training needs. *Maritime Technology 21ST Century Conference.* Melbourne: Australian Maritime College.

Muirhead, P. (1999). *Two hundred and fifty years of tradition versus new technology! Is the choice divorce or co-habitation for the navigation teacher in the 21st century?* World Maritime University, Malmö, Sweden.

National Research Council(NRC). (1994). *Minding the helm: Marine Navigation and Piloting. Executive Summary.* Retrieved May 21, 2008, from the World Wide Web: http://books.nap.edu/catalog.php?record_id=2055.

National Transportation Saferty Board(NTSB). (1997). *Grounding of the Panamanian passenger ship Royal Majesty* (p. 75). Washington D.C. 20594: National Transportation Safety Board. Retrieved May 22, 2008, from http://www.ntsb.gov/publictn/1997/mar9701.pdf.

National Transportation Safety Board (NTSB). (2008). *Heeling Accident on M/V Crown Princess. Atlantic Ocean Off Port Canaveral, Florida. July 18, 2006.* Washington, D.C. Retrieved May 22, 2008, from the World Wide Web:

http://www.ntsb.gov/publictn/2008/MAR0801.pdf.

Nautical Institute. (2007). Let's be clear about automation. *Alert - The International Maritime Human Element Bulletin*, (15). Retrieved June 9, 2008, from the World Wide Web: http://www.he-alert.org/documents/bulletin/Alert!_15.pdf.

O´Neil, W. (2001a, June 29). *The Human element in Shipping*. Retrieved July 03, 2008, from the World Wide Web:

http://www.imo.org/Newsroom/mainframe.asp?topic_id=82&doc_id=1212.

O´Neil, W. (2001, September 27). *World Maritime Day 2001: IMO - Globalization and the Role of the Seafarer*. Retrieved July 03, 2008, from the World Wide Web:

http://www.imo.org/Newsroom/mainframe.asp?topic_id=67&doc_id=1458.

Powers, D. (1999, December 15). *NUREG-1624, REVISION 1, "Technical basis and implementation Guidelines for a technique for Human Event Analysis (ATHEANA)"*. Retrieved July 20, 2008, from the World Wide Web: http://www.nrc.gov/reading-rm/doc-collections/acrs/letters/1999/4681870.html.

Reason, J. T. (1990). *Human error*. Cambridge [England]; New York: Cambridge University Press.

Rowley, I., Williams, R., Barnett, M., Pekcan, C., Gatfield, D., Northcott, L., Crick J. (2006). *Development of guidance for the mitigation of human error in automated shipborne maritime systems*. Retrieved June 6, 2008, from the World Wide Web: http://www.mcga.gov.uk/c4mca/research_report_545.pdf.

Satava, R. M., & Ellis, S. R. (1994). Human interface technology. *Surgical Endoscopy*, *8*(7), 817-820. Retrieved from the World Wide Web:

http://www.springerlink.com/content/u0681q8097587218/

Sea Systems Group. (2006). Human Factors Integration Management Guide (formerly STGP 10). Bristol, United Kingdom. Retrieved July 1, 2008, from the

World Wide Web: http://www.hfidtc.com/pdf/MAP-01-010.pdf.

Squire, D. (2005, January 15). *The human element in shipping*. Retrieved July 1, 2008, from the World Wide Web:

http://www.he-alert.com/documents/published/he00350.pdf.

Swift, A. (2004). *Bridge team management: a practical guide; including a new section on electronic navigation*. London: Nautical Institute.

Tarver, S., & Pourzanjani, M. (2003). Measuring and Sustaining the UK Maritime Skills Base: A Review. *WMU Journal of Maritime Affairs*, *2*(1), 5-15.

Thomson, R. (2008, April 24). *What constitutes a human factor?* Retrieved July 28, 2008, from the World Wide Web:

http://www.he-alert.com/documents/published/he00715.pdf.

United States Nuclear Regulatory Commision Office of Nuclear Regulatory Research(NUREG). (2007, June). *Atheana User's Guide (NUREG-1880)*. Washington D.C. Retrieved July 20, 2008, from the World Wide Web: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1880/sr1880.pdf.

Wilson, J. R. (2000). Fundamentals of ergonomics in theory and practice. *Applied Ergonomics*, *31*, 557-567.

Appendixes

Appendix A (IMO, 2005b)

Checklist for Consideration of the Human Element in the Work Program of IMO Committees, Sub-Committees, Working Rroups, Correspondence Groups	
Instructions 1 This checklist should be completed prior to finalization of development and/or amendment of mandatory and non-mandatory IMO instruments. Member States are encouraged to complete this checklist when proposing new instruments and amendments 2 If the answer to any of the question below is: (A) **YES**, the preparing body should provide supporting details and/or recommendation for further work. (B) **NO**, the preparing body should make proper justification as to why human element issues were not considered. © **NA** (Not Applicable) – no further action needed.	
Solution Being Assessed for Human Element System Integration	
Responsible Body: Committee, Sub-Committee, Working Group, Correspondence Group, Member State	
1 Was the human element considered in this the development and amendment of this solution?	□Yes □No □NA
2 Was the relationship of this solution to existing human element related instruments considered? (Identify instruments considered in comments section)	□Yes □No □NA
3 Have human element solutions been made as an alternative and/or in conjunction with technical solutions?	□Yes □No □NA
4 Has human element guidance on the application and/or implemantation of the proposed solution been provided for the following:	□Yes □No □NA
_ Administrations? _ Ship owners/managers _ Seafarers? _Surveyors?	□Yes □No □NA
5 At some point, before final adoption, has the solution been reviewed or considered by a relevant IMO body woth relevant human element expertise?	□Yes □No □NA
6 Does the solution address safeguards to avoid single person errors?	□Yes □No □NA
7 If the solution is to be directed at seafarers, is the information presented in a form that is both comprehensible and presentable?	□Yes □No □NA
8 Have human element experts been consulted in development of the solution?	□Yes □No □NA
9 **HUMAN ELEMENT INTEGRATION DOMAINS**: **Has the solution been assessed against each domain below?** This assessment should include (1) identification of affects; (2) risks of the affects; and (3) how the risks will be managed. The assessment should consider relevant affects upon passengers, crew, and ship owners/managers.	
□ MANPOWER. The number of qualified personnel required and available to safely operate, maintain, support, and provide training for system.	□Yes □No □NA
□ PERSONNEL. Personnel or *human* factors are the necessary human aptitudes (i.e., cognitive, physical, and sensory capabilities), knowledge, skills, abilities, and experience levels that are needed to properly perform job tasks. □ *Cognitive requirements* address the human's capability to evaluate and process information (i.e. response time). □ *Physical requirements* are typically stated as anthropometric (measurements of the human body), strength, and weight factors. □ *Sensory requirements* are typically visual, olfactory (smell), or hearing factors.	□Yes □No □NA
□ TRAINING. The process and tools by which personnel acquire or improve the necessary knowledge, skills, and abilities to achieve desired job/task performance.	□Yes □No □NA
□ SAFETY AND OCCUPATIONAL HEALTH. The safety management system procedures, policies, training, documentation, equipment, etc. to properly manage personnel safety and health risks? □ *Safety factors* are those system factors that minimizse the potential for mishaps causing death or injury or theraten the operation of the system. □ *Occupational health factors* are those system factors that minimize the risk of personnel injury, acute/chronic illness, or disability; and/or reduce job performance.	□Yes □No □NA

Checklist for consideration of the Human Element	
□ HABITABILITY. Living and working conditions that are necessary to sustain the morale, safety, health, and comfort of those on board. Beyond providing acceptable quality of life, habitability affects crew endurance, fatigue and alertness. Consideration should include but not be limited to noise, vibration, lighting, climate, and accommodation areas.	
□ PERSONNEL SURVIVABILITY. System features that reduce the risk of illness, injury, or death in a catastrophic event such as fire, explosion, spill, collision, flooding, or intentional attack. The assessment should consider desired human performance in emergency situations for detection, response, evacuation, survival and rescue and the interface with emergency procedures, systems, facilities and equipment.	
□ HUMAN FACTORS ENGINEERING. Designing human-machine, or more appropriately, *human-system interface* consistent with the physical, cognitive, and sensory abilities of the user population. □ *Functional interfaces:* Allocation of functions and tasks – role of the human versus automation. Manning levels, skills, and training. Objective: Ability to perform tasks within time and accuracy constraints. □ *Informational interfaces:* Information that provides the human with the knowledge, understanding and awareness of what is happening in the system. Information media, electronic, hard copy *Objective:* Ability to identify, obtain, integrate, understand, interpret, apply, and disseminate information. □ *Environmental interfaces:* Physical, phychologi8cal and operational environments. Natural and artificial environments, environmental controls, and facility design. *Objective:* Ability to perform under adverse environmental stress, including heat/cold, clothing/PPE, vibration, reduced visibility, weather, time constraints and psychological stress. □ *Co operational interfaces:* Team cooperation, collaboration, and communication among members and others. *Objective:* Ability to maintain performance over time. □ *Organizational interfaces: Job* design, management/organizational structure, command authority, policies and regulations. *Objective:* Ability to perform jobs, tasks, and functions within management/organizational structure. Should also include interface with contractors, partners, suppliers, customers, competitors, community, regulators, professional organizations and labour organizations. □ *Operational interfaces:* Such as procedures, documentation, workloads, job aids. *Objective:*Ability to maintain performance over time. □ *Cognitive interfaces:* Decision rules, decision support systems, provision for maintaining situation awareness, mental models of the operational environment, provisions for knowledge generation, cognitive skills and attitudes, memory aids. *Objective:* Ability to perform problem solving, decision-making, information integration, and situational awareness □ enable and facilitate effective and safe human performance and interaction. Includes controls, displays, workstations, work sites, accesses, labels, signs, structures, steps and ladders, handholds, maintenance provisions, etc. *Objective:* Ability to perform operations/maintenance using controls, displays, equipment, tools, etc.	
Comments: (1) Justification for NO Answers. (2) Recommendations for additional human element assessment needed. (3) Key risk management strategies employed. (4) Other comments. (5) Supporting documentation.	
Assessment Team: Name/Position	

Appendix B (IMO, 1998c)

Technical
(The vessel and/or its equipment)
! Design
! Ergonomics
! Manufacture/construction
! Installation
! Initial and periodic testing
! Approval
! Maintenance
! Repairs
! Modifications
! Renewals
! Expected marine environment1
! Operations2
Manning
(Master and crew of the vessel)
! Qualifications
! Number of crew members
! Composition of crew
! Culture3
! Working Language
! Medical Conditions
! Competence
Training
(Ashore and aboard)
! Basic Safety Training
! Familiarization
! Drills
! Extended safety training
! Training of personnel ashore

Management
(Ashore and aboard)
! Policy
! Safety culture
! Motivation
! Communication links
! Responsibility
! Authority
! Work planning
! Contingency planning
! Emergency response
! Manuals
! Procedures
! Instructions
! Work methods
! Checklists
! Education and Training
Work Environment/conditions
(aboard ship)
! Hazardous materials
! Man-machine interface
! Personnel protection
! Physical hazards
! Hours of work
! Hours of rest
! Fatigue
! Estimated workload5
! Actual marine environment
! Living conditions