Impact of Man-Machine Interface on Maritime Casualties

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ABSTRACT

Ships are complex sociotechnical systems consisting of technologies, people, organizational structure and environment. Human element is the weakest link in this system as the majority of maritime accidents are attributed to the human error. Understanding the limitations and abilities of human and adapting human to the other components is a proactive approach for maintaining safety at sea. Human errors are generally caused by technologies, environments, and organizations which are incompatible in some way with optimal human performance so ergonomic design principles should be applied to the points where there exist interfaces between machines, procedures, works, environment and human beings.

In this study different types of accident models will be compared by focusing human errors during design, assembly, installation, operation, inspection and maintenance phases of vessels. Also the role and contribution of applying ergonomic principles and "man-machine interface" concept to shipping industry in reducing human errors is examined.

1. Introduction

Maritime casualties are one of the most important subjects within the maritime community. The adverse effects of maritime transportation as grounding and collisions had been effecting only a limited group of people as ship owners, cargo owners and the crew members of vessels in the past, but as the carrying capacities of vessels have been increased and many types of dangerous cargoes have been transported in great amounts, the results of these casualties are effecting great groups and in great periods of time. Some major disasters have resulted in massive pollution and loss of human life and loss of huge amount of goods in the last several decades. This situation accelerated researches related identifying the causal factors of casualties and eliminating them to maintain a safer and efficient Maritime Transportation System.

It is a widely accepted fact that human factor play an important role in maritime casualties. Most of the human errors tend to occur as a result of technologies, work environments, and organizational factors which do not sufficiently consider the abilities and limitations of the people who must interact with them. System generally put people in situations where there is not any alternative for them other than making an error (Pesch,1978). Other industries like Nuclear energy and aviation have shown that human error can be controlled through human-centered designs and approaches. By applying some ergonomic techniques; new technologies, work environments, procedures and organizations which support the human operator for safety can be designed. Adapting the system and technologies to the limitations and performances of human has many benefits, including increased efficiency and effectiveness and reducing the human errors (ABS,2003;CORDIS RTD,1998).

2-Human Factor in Maritime Accidents: Literature Review

Maritime transportation is a complex socio-technical system formed by four interdependent factors as technology, environment, people and organizational structures (Committee, 1994). Each of these dimensions has direct or indirect effects on maritime casualties, but failures of human action and judgement have often been seen as an important part of the causes, and in a growing number of accidents the main cause has been attributed specifically to "human error". In the 1960s the impact of human error was accepted around 30%, but grew during the following decades so rapidly that the number at present is as high as 70-90% in maritime transportation. The human factor is now the most common explanation for accidents and the operator is often regarded as the weakest link in the system. To eliminate the role of human weaknesses, systems are need to be re-designed to correct human error.

In 1836, because of the larger number of shipping loses in the first half of the 19th century a committee appointed to investigate the causes of these losses in United Kingdom. The committee's report showed clearly the causes of shipwreck were as follows (Upham, 1978):

1- Poor standard of training of merchant service officers and ratings,
2- The defective construction of vessels,
3- Inadequacy of equipment,
4- Imperfect state of repairs,
5- Improper and excessive loading,

The causes of marine accidents seem not be changed until now. But the most important part is that "human factor" was firstly defined as lack of education of officers and ratings. This is very normal as untill the middle of 20th century most of the human-based errors were attributed to only to lack of education. A turning point seems to have come during the Second World War. Despite functional technical systems, airplanes crashed, bombers with modern sights missed their targets and technically superior weapons systems were defeated by inferior ones. As a result, psychologists were called in to analyze the connections between man and machine. The result was in-depth studies of human errors and factors which affect the relationship between people and technology (Schager, 1998).

In early 20th century. "Adapting people to technology" had the priority and this approach was the prevailing strategy to eliminate errors. The means were education, training and experience. The major emphasis of behavioral scientists through WG II was on the use of tests for selecting the proper people for jobs and on the development of improved training procedures but studies from the Second World War showed that even well-trained, experienced operators could make mistakes. It become clear that even with the best selection and training the operation of some of the complex equipment and systems still exceeded the capabilities of the people who had to operate it (Sanders and Mc Cormick, 1993). This gave rise to questions about which tasks were suitable for people and which were more suitable for technical solutions. The interface between operator and technology was given the highest priority. After the WW-II new dimensions of human factor, like the connections between man and machine were examined. A new era, "adapting technology to people" commenced and parallel to this, "Human error is the cause of many accidents" approach has shifted to "Human error is a symptom of trouble deeper inside the system" approach.

Accident models are the methods for understanding the causes of accidents. The analysis of an accident is always based on an accident model, a conceptualization of the nature of accidents, specifically how a set of causes and conditions may lead to an accident. Current accident models must account for the complex interaction between humans, technology, and organizations. Every accident model is based on the principle of causality, which states that there must be a cause for any observed event, and the models serve as guidance for finding the acceptable causes.

"Simple Accident Model" tended to see accidents as caused either by failures of the technology or incorrect human actions. "Intermediate Accident Model" examined the contribution of latent system states, and the complexity of conditions that could lead to an incorrectly performed human action and "error forcing" conditions. It is focused on how human actions were affected by the conditions under which they took place.

With the "Contemporary Accident Model", the common approach for analyzing and understanding accidents has in the 1990s further shifted the perspective from individual actors to the organizational context. There has been a marked shift of emphasis towards a wider acknowledgement of the situational, managerial, organizational and regulatory contributions to system breakdown (Karwowski,2001). Although the actions and failures of individuals still constitute the initiating or triggering the event, it is necessary to understand the complexity of the working environment, not least the existence of latent conditions.

In this current approach, the immediate or proximal cause of the accident is a failure of people at the sharp end who are directly involved in the regulation of the process or in the interaction with the technology (officers, pilots, masters, ratings). A combination of factors that relate to either the human, the technological, environmental or the organizational parts of the system is creating this failure. The failure at the sharp end is only the triggering condition. The accident occur when a number of latent conditions that suddenly become "active". People at the blunt end are responsible for the conditions to which by people at the sharp end are exposed, but they are generally isolate themselves from the actual operation. They can be people at the design, installation, inspection, maintenance phases, managers, regulators, system architects, instrument providers, etc. (Hollnagel, 1999).

On the other hand, "System induced error" concept suggest that people have in-built error tendencies which, when combined with "error-inducing conditions" such as distraction, time stress, poor communication, fatigue, faulty leadership and management, poor design etc., compound to give predictable errors. The operator, the last link in the chain of causation, is powerless to alter the way in which carries out his job or the soft and hardware used in process control (SIGTTO,1990).Creating a "error-free" transportation system may be difficult or impossible but we can focus all our efforts to create an "system induced error-free" working environments. System induced error theory does not remove the responsibility for actions from individual operators but allows correct assignment of responsibility by identifying factors like organizational management or system, within or outside an individual's power to control.

Term "Situation-caused errors" defined in "Guidance On Fatigue Mitigation And Management" by IMO is parallel with the above mentioned approach. Situation-caused errors arise from the working environment, design of the workstation (bridge), organizational matters, range and quality of instrumentation and the so-called Man-Machine Interface (MMI) or Human Machine Interface (IMO,2001). So "Situation-caused errors" or "System-induced error" are different than "Human errors". Human errors arise from professional qualifications and personal quality of the operator. The difference between two should be well defined in order to find the root causes of accidents.

3. Man-Machine Interfaces In Marine Transportation

M/T Torrey Canyon ran aground on a clear, calm weather while proceeding through the Scilly Islands, transiting the English Channel and spilled 100,000 tons of oil. Besides many other types of errors, equipment design error had played an important role in this accident. The steering selector switch had been left on autopilot. Unfortunately, the design of the steering selector unit did not give any indication of its setting at the helm. So when the captain ordered a turn into the western channel through the Scillies, the helmsman dutifully turned the wheel, but nothing happened. By the time they figured out the problem and got the steering selector back on "manual", it was too late to make the turn, and the Torrey Canyon ran aground (Rothlum, 2003). Herald of Free Enterprise capsized because of not having bow door remote indicator lights on the bridge, although these indicators were required with a memorandum to the managing director of the fleet by a master of a same class vessel of the same company one year before the accident. If they had installed these indicator lights, 200 lives might have been saved (Cahill, 1992).

Man-machine interface (MMI) covers a broad area which is traditionally considered to be relevant to the physical relation between the operator, machinery and equipment such as type and color of alarms, automation, bridge layout and ergonomics but in general deals with the working environment on board, both from the safety and effectiveness of human performance points of view (Cazzulo, 1996).

In the United States the person whose processional occupation involved this man–machine orientation came to be called a "human factor engineering". In Great Britain and Europe the new field was termed ergonomics. Human factor technology has not been a major feature in the design of contemporary surface ships and systems (Mead, 1978).

The importance of man-machine interface (MMI) to reliable human performance is widely recognized especially in nuclear energy industry (Kim, 2001). MMI approach first applied in nuclear industry where safety precautions have been adapted very strictly. In an International Atomic Energy Agency (IAEA) safety report in 1997, it is stated that ''The human–machine interaction problems are complex. In many applications, the role of the human operators is often neglected in design and the human functions are defined by default, governed by the limitations and gaps of hardware and software.......Changing role of the operator because of higher level of automation both in the nuclear and the non-nuclear industry, need to be considered" (Øwre,2001).

When technological innovation occurs there follow personal dilemmas of adaptation and integration to new man-machine systems (Mead, 1978). The complexity of the interface between machinery, computers and personnel on board, for normal operations and during an emergency, needs a careful assessment of the effects of failures of such systems in relation to the risks to people, the environment or commercial losses.

The performance of these ship's crew, pilots, on board will be dependent on many traits, both innate and learned. As human beings, we all have certain abilities and limitations. Human has some special features compared with the technology or the machines such as; Sensing unusual and unexpected events in the environment, making subjective estimates and evaluations, developing entirely new solutions, having decision making skills, affected by psychosocial issues including stress, requiring breaks, great at pattern discrimination and recognition, in addition to these inborn characteristics, human performance is also influenced by the knowledge and skills we have acquired, as well as by internal regulators such as motivation and alertness. On the other hand machines sense stimuli outside the normal range of human sensitivity, such as x-rays, radar wavelengths, and ultrasonic vibrations, performing repetitive activities reliably, exert considerable physical force in a highly controlled manner, perform several programmed activities simultaneously, maintain efficient operations under distractions, precision of operations, repetition without failure, single-task oriented, can work 24 hours a day, one part failure can shut the entire line down (1). So the relation between man and the machine should be designed by taking into consideration the factors mentioned above in shipping sector.

The term MMI in shipping covers a broader area including the whole vessel with its environment, technology, automation, work stations, living and working areas, ergonomics, organizational structure, the work procedures etc. These interfaces must suit the limitations and abilities of the operators.

4. Human Factor and System Integration

Ships are complex sociotechnical systems consisting of *technologies* which is a function of design, construction, system integration, automation, computerization, simulation, etc., *people* which is a function of competence, training, experience, workload, stress, health, attitude, prejudices, judgement, etc., *organizational structure* which is a function of organization and levels of authority, responsibility, communication of shipboard and ashore personnel, and *external environment* which is a function of weather, time of day, congestion, physical or personnel interactions, layout of the workspace, man-machine interface, etc. These four dimensions are interdependent, when one change it affects the other three so introduction of for instance new technologies, new organizational structures, changes in external environments and behaviors of human can not be seen in isolation (Committee, 1990;Cazzulo, 1996;U.S. Coast Guard, 1995).

Human errors are generally caused by technologies, environments, and organizations, which are incompatible in some way with optimal human performance. A balance between these factors should facilitate the design, construction and maintenance of ships to be tolerant or forgiving of human errors during the ship's life, by keeping them simple e.g. easy to operate by qualified personnel, robust e.g. damage, defect or error tolerant, durable e.g. easy to inspect, repair and maintain, and effective e.g. fit for the purpose, at low risks to safety and the marine environment and at reasonably low costs (Cazzulo, 1996).

4.1 Impact of New Technologies on Human Factor

The introduction of new technologies in ships sometimes damage the harmony between man, machine, management and environment. These changes, adaptations and implementations must be well planned and tested extensively before full implementation. THALASSES project of EU comprises impacts of the human factor in shipping due to the introduction of new technologies. The term new technology in the context of the this project is defined as "a technology that has already been implemented on board ships/harbor and/or is expected to be implemented to a large extent in the near future" (European Commission, 2000).

Impact of new technologies on human element must be determined and examined because implementation of a new technology that is not suitable with the limitations and performances of human will be a human error inducer during operations. The impacts of new technologies are listed below:

- A more indirect relationship between workers (operators) and machines;
- A reduction in the number of complex multitasks which require manual skills and abilities (de-skill);
- A generation of new complex tasks which require mental cognitive problem-solving and interpretative skills and abilities, and an understanding of system interdependencies (up-skill);
- In order to deal with operating contingencies which are not anticipated by the programs controlling the machine, experience associated with the performance of work with the old technology are still required.

Main categories of new technology have been examined with considering the impacts on crew on board are mentioned below.

4.1.1 Ship Design Related New Technologies

The design related new technologies are defined as the development of new vessel types and the design of the interior of the ship. There are three main sub-categories of design related new technologies can be distinguished that each have their own impact on the maritime working culture. The three main sub-categories are Ship size, Ship speed and Ergonomic design of the interior of the ship. The increase in ship size is still going on. The main socio-economic impacts are the reduction in the number of seafarers that are needed per shipped tonne of cargo, and a decrease in the time that the seafarer can spend in the port while the ship is (un) loaded.

The main conclusions of the impact of design related new technologies on the human factor, via vessel speed, are illustrated by the fast ship concept. The socio-economic impacts of the fast ship are:
1- The extra workload for seafarers of working in an environment where there is less room for mistakes,
2- The need for extra training to work in a new type of vessel,
3- To work with modern navigation support technologies, and
4- To work to airline style schedules.

4.1.2. Cargo Related New Technologies

New technologies related to cargo are defined as innovations in cargo storage on board the ship and cargo handling. Containerization has led to more shore-based handling of the cargo and to a rapid turnaround of vessels. This reduces the time that the seafarer spends ashore. The improvement in cargo handling and planning on board ships is further improved by the use of computers. This leads to a reduction in operational tasks for the people on board and an increase in passive monitoring, and also it requires knowledge from the people who have to work with these new systems.

4.1.3.Navigation Support Related Technologies

The navigation support related technologies are the technologies that are used for the communication between the functions and systems on board a ship for data exchange and the common use of sensors and facilities, that support the navigational officer in defining his route, maneuvering and collision avoidance. This group of technologies refers to technologies such as automated pilots, GPS, ECDIS, and ARPA. The implementation of navigation support technologies can reduce the repetitive tasks and the workload for the seafarers, if the number of crewmembers remains unchanged.

The navigation support related technologies might also lead to a reduction of the number of ship accidents. More time can be spent on decision making, instead of collecting and processing data. The implementation of navigation support systems makes it possible to integrate functions and can lead to a reduction in the number of crewmembers that are needed to operate the ship, which is likely to lead to an increase in mental workload.

4.1.4. Communication & Management Support Related New Technologies

Communication and management support related new technologies are defined as the technologies that are used for the communication with the outside world, that supports traffic management systems and shore based management of the ship. This category of new technologies contains technologies such as GMDSS, EDI and Internet.

4.1.5. Machinery Related New Technologies

The machinery related new technologies are defined as all the machines and technological appliances that are needed for the operation of the ship, which are not information or cargo related.

The level of user acceptance is very important as creating a harmony between new technologies and operators. The level of user acceptance is much dependent on the reasons why the new technology will be implemented. The following motivations can be found for implementation of new technologies in the maritime industry:

1. Safety considerations: contributing to disaster prevention and pollution;
2. Regulatory requirements: a minimum level of technological equipment is required by regulatory institutions;
3. Cost-effectiveness (cost-push): the intense global competition stimulates the use of new technology as a contribution to the reduction of operational costs
4. Customer demands: some technological concepts are developed to (better) fulfil customer needs such as faster or more environmentally friendly transport;
5. Technological innovation (technology-pull): new designs fresh from the drawing table may create their own demand;
6. Improvement of working conditions and quality of life on board ships: in order to attract appropriate personnel, ship owners may want to invest in technology applications which provide for instance better ergonomics or workload reductions.

In this project it is concluded that new technologies that have been implemented for reasons of safety and improvement of working conditions have a much bigger chance of immediate user (crew) acceptance than for instance new technologies based on customer demands or cost effectiveness because the relationship with the crew's interest is more direct. Of course this acceptance has a great contribution on safety issues.

4.2. Impact of Automation on Human Factor

The role of automation is to replace human manual control, planning and problem solving by automatic devices and computers. High degree of automation distances the operator from the process being controlled so that in the event of emergency situation the operator is not full possession of all relevant information required to provide an up to date mental picture of the process. Automated computer systems are only as good as system designer and software programmer and it is essential that human error is avoided in design and writing the software. Evidence suggest that over 60% of automation errors are committed during the specification/requirements and design phases and the remainder during the software coding (SIGGTO,1990).

Increased automation on board the ship has resulted in a shift from physical work demand towards mental work demand. Mental work demand is related to the perceptual-cognitive demands of monitoring the technical systems. Too much mental work demand may result in fatigue, boredom and stress for the seafarer (European Commission, 2000). There is also a risk for too much reliance on automation instead of traditional navigational skills, so that seafarers forget how to handle dangerous situations when the navigation support systems fail to do their work.

A highly automated working process, which can be found on modern ship systems, is marked by an especially high demand of human information processing and ability of decision-making. The flow of information between man and technical system components should accommodate human attributes and abilities. The amount of information supplied to the officers by systems that are more than the capacity to handle, can cause delays in decision making processes and poor decisions.

4.3. Impact of Management Policies on Human factor

Management policies can induce errors by providing inadequate resources for human aspects of a system. Inadequate or poorly designed management policies will most likely result in operating procedures not being generated or, if produced, not being realistic, not keep up to date or not enforced. Management policies and attitudes may contribute to difficulties in communication between individuals, shifts, departments or level in organization, with inadequate feedback of operational experience(SIGGTO, 1990).

Organizational factors, both crew organization and company policies, affect human performance. Crew size and training decisions directly affect crew workload and their capabilities to perform safely and effectively. A strict hierarchical command structure can inhibit effective teamwork, whereas free, interactive communications can enhance it. Work schedules, which do not provide the individual with regular and sufficient sleep time produce fatigue. Company policies with respect to meeting schedules and working safely will directly influence the degree of risk-taking behavior and operational safety (Rothlum, 2003). One of the main features of work organisation on board ships is the segmentation in functions. A rigid segmentation may result in little co-operation between persons, isolation and a high autonomy level for crewmembers. (European Commission, 2000).

A strategy against the negative effects of the human factor is to organize work so as to prevent accidents. The purpose of an organization is normally to involve several people interactively in the same operation, thereby minimizing the risk of an individual operator acting erroneously. A good organization means an efficient division of labor, where several operators handle the available information, evaluate it jointly, and observe and challenge each other’s actions. This is based on the notion that many operators perceive more than one and have greater combined experience and knowledge. In this respect, aviation has made greater progress than the maritime industry, which is still largely traditional, hierarchical and authoritarian. Bridge Resource Management, courses modeled on aviation are widely introduced in MET institutions.

4.4. Impact of Environment on Human Factor

The environment affects human performance. Term "environment" is not only including weather and other aspects of the physical work environment (such as lighting, noise, and temperature), but also the regulatory and economic climates. The physical work environment directly affects one's ability to perform. For example, the human body performs best in a fairly restricted temperature range. Performance will be degraded at temperatures outside that range, and fail altogether in extreme temperatures. High sea states and ship vibrations can affect locomotion and manual dexterity, as well as cause stress and fatigue.Tight economic conditions can increase the probability of risk-taking (e.g., making schedule at all costs) (Beaty,1995). On the other hand economic pressure is perceived an important factor by the officers on safety issues (Asyali, 2001).

5. Applying Ergonomic Principles to Maritime Industry

In some industries like nuclear and chemical industries, rail and sea transport and aviation, including air traffic control the impact of human errors can be catastrophic. When disasters occur, the blame is often laid with the operators, pilots or OOW and labeled "human error". In detailed investigations and applying advanced models in some accidents, it is found that the errors are caused by poor equipment, work and system design.

The discipline of ergonomics is founded on the belief that good design supports human performance and is not limited to aesthetic qualities. A well-designed work system or piece of equipment, from an ergonomics viewpoint, takes advantage of human capabilities and minimizes the impact of human limitation while ensuring that the equipment or system is fully functional, (IMO, 2001a)

Ergonomics is a relatively new branch of science but relies on research carried out in many other older, established scientific areas, such as engineering, physiology and psychology. It originated in World War 2, when scientists designed advanced new and potentially improved systems without fully considering the people who would be using them. It gradually became clear that systems and products would have to be designed to take account of many human and environmental factors if they are to be used safely and effectively. This awareness of people's requirements resulted in the discipline of ergonomics (2).The development of ergonomics has been inextricably interwined with the developments in the technology and as such had its beginnings in the industrial revolution of the late 1800s and early 1900s (Sanders and Mc Cormick, 1993)

According to the definition of International Ergonomics Association, (2000) Ergonomics (also called human factors engineering) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance (ABS,2003).

Ergonomics produces and integrates knowledge from the human sciences to match jobs, systems, products, equipment, facilities, procedures and environments used in work and everyday living to the physical and mental abilities and limitations of people. In doing so, it seeks to enhance the effectiveness and efficiency with which work and other activities are carried out to increase convenience of use, reduced errors and increased productivity and also to enhance certain desirable human values, including improved safety, reduced fatigue, and stress, increased comfort, greater user acceptance, increased job satisfaction and improved quality of life (IMO, 2001a; Sanders and Mc Cormick,1993). The focus of ergonomics is the design of the human-system interface. This includes interfaces between personnel and the hardware, software, and physical environments associated with systems. It also involves the interfaces between personnel, individual tasks, and the overall work system (e.g., its structure, management, policies, and procedures).

The maritime industry is becoming increasingly aware of, and is responding to, the important role of the human element within effective safety standards and practices. With increased attention to human element concerns being paid by national and international organizations, it is expected that the application of ergonomic data and principles to maritime systems will expand rapidly. Although many studies and authorities cite human error as the principal component for a majority of maritime accidents, the amount of ergonomic design guidance available to marine architects, designers, and engineers remains sparse (ABS,2003). Objectives of ergonomics as applied to maritime systems are:

1- Reduced workload and manning;
2- Improved readiness of control systems due to reduced skills, reduced workloads, and task simplification;
3- Improved reliability of ships and ship systems due to reduction of human error rates;
4- Improved personnel availability and survivability due to reduced hazards and accidents;
5- Enhanced system and equipment availability through reductions in time to repair; and
6- Enhanced system affordability, resulting from the reductions in manpower support cost, training cost, cost of systems unavailability, cost of human errors, and cost of accidents.

While organizations, like IMO, have issued documents, circulars, and guidelines related to aspects of ergonomics, systematic application of ergonomics in the maritime industry remain limited. This lack of systematic application occurs even though ergonomics has been recognized to be central to improving safety and productivity (ABS,2003). IMO adapted "Guidelines On Ergonomic Criteria For Bridge Equipment And Layout" MSC/Circ.982 on 20 December 2000 that is developed to realize a successful ergonomic design of the bridge and the equipment on the bridge, which will improve the reliability and efficiency of navigation. This Guideline contains ergonomic requirements as well as a functionally oriented bridge layout to support watch-keeping personnel in their tasks by a user-centered design of the bridge equipment and layout.

Regulation 15 of SOLAS Chapter V deals with principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures bridge design, the design and arrangement of navigational systems and equipment on the bridge and bridge procedures shall be taken with the aim of:

1- Facilitating the tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions;
2- Promoting effective and safe bridge resource management;

3- Enabling the bridge team and the pilot to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays;
4- Indicating the operational status of automated functions and integrated components, systems and/or sub-systems;
5- Allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot;
6- Preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the bridge team and the pilot;
7- Minimizing the risk of human error and detecting such error if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action (IMO, 2001b).

The Regulation addresses designers, naval architects, manufacturers and shipowners with respect to the bridge design and layout. However, masters and watchkeepers are responsible for ensuring the efficient deployment and use of bridge resources.

6. Conclusion

Modern safety management emphasizes the proactive approach in planning, organization and measurement (Karwowski,2001).The safety culture in the shipping industry, should be more proactive rather than reactive against maritime accidents. The starting point can be applying ergonomic techniques at the design stages of shipping systems. Most of the human errors occur as a result of technologies, work environments, and organizational factors, which do not sufficiently consider the abilities, and limitations of the people who must interact with them. Other industries like nuclear energy, and aviation have shown that human error can be controlled through human-centered design. Ergonomics principles and criteria should be considered during the design of a vessel. A development effort without ergonomics considerations is likely to result in designs that encourage human error (ABS,2003; Committe,1994; Karwowski,2001).The design of technology can have a big impact on how people perform. Ergonomic ship designs aim to adjust the systems on board the ship to the physical and mental capacity of the seafarer. This has a positive effect on the mental workload and the occupational health of the operators and maintenance people on board the ships (European Commission, 2000).

The discipline ergonomics is devoted to understanding human capabilities and limitations, and to applying this information to design equipment, work environments, procedures, and policies that are compatible with human abilities. In this way we can design technology, environments, and organizations which will work with people to enhance their performance, instead of working against people and degrading their performance. This kind of human-centered approach has many benefits, including increased efficiency and effectiveness, decreased errors and accidents, decreased training costs, decreased personnel injuries and lost time, and increased morale.

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