Definitions of human factor analysis for the maritime safety management process

Z. Er & M. Celik
Department of Marine Transportation and Management,
Maritime Faculty of Istanbul Technical University, Turkey

Abstract

There has been a growing recognition that human errors, rather than equipment problems, have been responsible for approximately 62% of pollution and marine accidents over the past 15 years. Human factors in the following categories are resulting in 15% rating error, 30% deck officer error, 2% engine officer error, 8% pilot error and 7% shore-based personnel error. In the maritime domain the root causes of accidents and the casualties can be sub-classified as mechanical failure or in general terms reliability failure (non-human) and the human error that has direct effect on the accident occurrence. At this stage human error can be classified in three major categories with the same approximation of the STCW Code 1995 amendments. The first category is operational based human errors, the second category is the management based human errors and the third category is the combination of the first and second category that might cause a considerable accident or disaster by triggering chain events. In this respect the terminology of an incident might be described as a triggering event, such as a human error or a mechanical failure that creates an unsafe condition and might result in an accident. Hence the root cause, the immediate cause, the incident, accident, consequence and its impact can be defined as the casual chain. Accidents that occur in complex systems are determined by internal and external factors and the term triggering event has a great significance, rather than causal event, to describe the final stage of the accident chain. The aim of this paper is to categorize a quick and easy method for the collection of knowledge about human error in the maritime safety management process and the description of the human factor using accident reports as empirical material.
Keywords: *human factor, safety management, shipping, IMO requirements, human error, taxonomy in ergonomics.*

1 Introduction

The design and operation of ships has evolved and continues to develop, driven by structural change in the industry, new technologies, new regulations and changes in manning. When considering maritime safety, it is necessary to address both the human factor and the technical solutions in the broadest sense, not just the immediate causes of actual or potential failures. Whilst this combined approach is taken in some incident analysis, whether after the event or as part of a proactive safety assessment, there is still a tendency to treat the human and the technical elements independently of each other. An integrated approach is required if full understanding is to be achieved. A simplistic technical approach tends to recommend local reactive solutions, such as the addition of more alarms, which may assist but will add complexity so the underlying cause may not be resolved. A purely human factor approach tends to promote administrative solutions, which may not be fully effective on their own. Of course, there are many aspects of ship design that have a direct impact on human performance, such as ship motions, accessibility, lighting and noise levels and basic habitability. Classification Rules provide some cover for these aspects but the maritime industry needs to grasp human factor issues at a higher, more integrated level to make a real difference to safety. There are many lessons to be learned from the experience of other sectors, to prevent the maritime industry learning the same lessons the hard way.

2 Definitions of basic terms

Human Factor is the body of scientific knowledge about people and how they interact with their environment, especially when working. Human Factors, or the Human Factor, are terms which are often misinterpreted and are used as covers for the Human Element or even Human Error. A simple way to view human factors is to consider three main aspects: the person, the job (task, environment and equipment), and the organization and management, and how they together with the environment in which the organization and person are operating and the impact on the behaviour of people.

The term "the human element", or "the human factor" is often heard in conversations of persons having little or no true knowledge of "human factors" or "human factors engineering". It is often used by persons to express their personal bias or prejudice concerning the behaviour of certain people related to a specific event being examined. When something goes wrong, the term "the human element" is typically used. In this sense, it is an attempt to blindly judge or blame people as being "idiots", or worse. As such, it is a term that should not be used by human factors professionals.

Applying human factors to the design and operation of a ship or its systems means taking into account human capabilities, skills, limitations and needs. Human Factors should not be confused with the term Human Resources which is a closely related activity that addresses the supply of suitably qualified and experienced staff. When considering the operation or design of any ship and its systems both of these domains should be considered as Human Resources for the selection and preparation of staff able to do the required work and Human Factors to account for the use of people as a component of the system. Both domains contain a number of sub-domains:

Human Factors (Fitting the job to the person):

- Human Factors Engineering – The comprehensive integration of human characteristics into the definition, design development, and evaluation of a system to optimize Human-Machine performance under specified conditions.
- Health Hazards - The identification, assessment and the removal or reduction of short or long-term hazards to health occurring as a result of normal operation of a system.
- System Safety - The human contribution to risk when the system is functioning in a normal or abnormal manner.

Human Resources (Fitting the person to the job):

- Manpower - the number of personnel required, and potentially available, to operate, maintain, sustain and provide training for a system.
- Personnel - The cognitive (trainability and mental aptitude) and physical (fitness levels, physical size, gender) capabilities required to be able to train for, operate, maintain and sustain a system and provide optimum quality and quantity of the crews to man the ship.
- Training - The instruction or the education, and on-the-job or part-task or full-mission training required to provide personnel with their essential job skills, knowledge, values and attitudes.

On the other hand human engineering has been defined (similar to the term "human factors engineering") as a discipline concerned with designing man-made systems so that people can use them effectively and safely, and the creation of environments suitable for human living and work [1].

2.1 Human factors viewed as human characteristics

The phrase "human factors" is often used to mean "human characteristics". Various human factors in this sense generally fall into one of three groups of human characteristics: (1). physical characteristics, (2). physiological characteristics, and (3). psychological or behavioural characteristics. These groups of human factors are not necessarily mutually exclusive. Here human factors are defined the nature of our "humanness", that is, the characteristics of "being human".

Physical human factors include physical attributes of the human body, such as height, weight, arm reach, and centre of gravity. Physiological human factors include such things as muscle strength and endurance in different body positions, visual acuity, tolerance to extremes of temperature, and frequency range of human hearing. Psychological or behavioural human factors include things such as mental reaction time to various stimuli, various acquired meanings associated with certain colours (red often means "danger"), the capabilities and limitations of short term memory, and "expectancy" as an element of perception. In addition, there are cultural norms that must also be taken into account. For example, in the standard international cultural environments, electrical switches go "up" to turn on and "down" to turn off; hot water valves are on the left of the faucet outlet and cold water valves are on the right; electrical dials turn clockwise to increase flow, but a fluid valve turned clockwise will decrease flow.

As a competent person, the human factors specialist or engineer does not attempt to judge human factors as right or wrong, correct or incorrect. Rather, the human factors specialist merely attempts to understand and define these factors, or human characteristics, so that their strengths and weaknesses, and their capabilities and limitations might be taken into account when designing systems where persons are to be an essential component.

2.2 Human factors engineering

Human factors engineering is the discipline dedicated to optimizing the relationship between technology (system hardware and software) and the human operator of various systems. Any man-machine system can and should be the target of human factors engineering [2]. Human factors engineer designs things to provide the "best match" between system user capabilities and limitations and the relevant system hardware components that impose physical, physiological, and/or psychological demands on such users.

2.3 Ergonomics

The terms ergonomics and human factors are often used synonymously. Both describe the interaction between the operator and task demands, and both are concerned with trying to reduce unnecessary stress and resulting injury to persons engaged in a certain activity or operating certain equipment. The term ergonomics originated as a European term while the term human factors is more often used in the United States [3].

3 Human error

Errors occur both as random events and in situations where the design of a system, a procedure, or of the intended interaction between a human and a system is faulty in that such interaction makes human actions prone to error. Thus it is not sufficient just to make a generalized statement about human error, such as to error is human, without knowing the mechanisms which are at work and which may provide some explanation concerning errors that are committed. Knowing this information will help in the understanding of errors and in supporting the detection, diagnosis and correction of errors.

Sanders and McCormick [4] defined human error as an inappropriate or undesirable human decision or behaviour that reduces or has the potential for reducing effectiveness, safety, or system performance. Two things should be noted about this definition. First, an error is defined in terms of its undesirable effect or potential effect on human performance and systems operations. Second, an action does not have to result in degraded system performance or an undesirable effect on people to be considered an error. As a result the decision or action has the potential for adversely affecting the system operations or human performance for it to be considered an error.

In the analysis of human error in industrial plants, 80 to 85% of the errors that occur are attributable not to human characteristics, but to error-likely conditions [5]. In these situations, people are "set up" for error by the system design. These error-inducing situations include deficient procedures, poor communication, inadequate training, misleading information, and poor equipment design. Many of these errors are entirely preventable. Identifying error likely situations is a first step toward minimizing or eliminating errors.

In addressing human error reduction, Wiener [6] states that the first step in error reduction is to identify the errors. Identifying human errors is not always a straightforward task. Errors can be obvious but are more often subtle. There are six methods of identifying potential errors that have been used successfully in other industries. They include brainstorming using representatives of the area of interest; critical incident techniques; structured walkthroughs or reviews of standards, procedures, or systems; surveys and questionnaires; observation; and analysis of confidential reporting systems [6]. Once potential errors are identified, a risk assessment should be done to weigh the potential errors according to their severity. The next steps in effective error management are to identify the current defences, evaluate the effectiveness of the current defences, and identify additional defences needed. Finally, an effective mechanism should be established for reporting potential errors and addressing them once they are identified.

3.1 Human error viewed as human nature

Humans are bound by specific innate characteristics, which are not subject to significant change, but dictate specific behaviour under particular circumstances. Such behaviour must be considered as part of human nature and not mislabelled as human error. Human error may result from a combination of human nature, random error, design induced human error, and true human error.

3.2 Human error viewed as random error

True human error must be distinguished from random error. Random errors committed by system operators are non-predictable by both system designers and operators. An example of a random error would be the reflex action that causes a wrong control to be activated as a result of an unexpected mosquito bite. Random errors can also involve improbable but normal extremes of human variation. For example, even persons who are well trained and have repeatedly used a well-designed system will occasionally make inadvertent errors related to rare and unintended (and uncontrollable) variations in required hand-eye coordination.

3.3 Human error viewed as design induced human error

An axiom of human factors engineering states that, “How a system is designed will dictate how it can and will be used”. True human error must be distinguished from design induced human error where some (engineering or administrative) aspect of the system design (such as a lack of safety features, the presence of reasonably anticipated operator distraction or overload, or the presence of excessive or contradictory system demands) predisposes such error; that is, where the system operator is set up to make the error by some design aspect of the system. Such errors, if they can rightfully be called errors at all, are predictable and therefore preventable through re-design.

3.4 True human error

True human error is most properly defined as an action that would not have been committed (or an action that would not have been omitted) by ordinary, reasonably prudent persons under the same or similar circumstances, while taking common human factor limitations into account, and after eliminating other forms of human error from consideration.

True human error can only be said to occur when the system in which it takes place has been well engineered (according to the basic principles and reasonable application of safety engineering and human factors engineering) and the demands imposed on adequately trained system operators are realistic in relation to human factor (human nature) capabilities and limitations of such persons. Only under such circumstances is the system operator truly free to choose his or her actions.

One method that can be useful to distinguish between true human error and other forms of alleged human error is to ask this question: If a thousand reasonably prudent persons were placed in the same or similar circumstances, would a significant number make the same or similar error? If so, one's search for causation must go beyond the apparent identification of simple human error.

3.5 Primary human error and incidental human error

Primary human error can be thought of as error made by those who have a primary assigned or special responsibility and the special expertise to focus on the subject matter of the error. An incidental human error, in contrast, is error made by those who have a secondary or oversight responsibility or lack the special expertise to focus on the same issue.

3.6 Slips, lapses and mistakes

The most common types of error in everyday life are slips and lapses. They are usually treated together, as they are psychologically related and occur in the same mental modes and for similar reasons. They occur mainly in skilled behaviour, and examples include a misplaced action, the wrong thing moved or simply forgetting an intended action [7].

The difference between slips and lapses is that slips relate to observable actions, associated with attention or perceptual failures, whereas lapses are more internal and generally involve failure of memory [8]. Slips have nothing to do with the validity of the goals set up for the particular action, they are simply errors committed when trying to reach that goal, right or wrong. But when the goal is in itself inappropriately chosen, the error is classified as a mistake. Mistakes occur at higher mental levels (i.e. errors of thought), and examples include misjudging a situation or making poor decisions [7]. Reason [9] puts it this way: mistakes are linked to the planning stage, lapses to storage stage and slips to the execution stage.

4 IMO requirements relating to human factor analysis

In 1997, the IMO Assembly adopted a Resolution that indicated a step change in its approach to maritime safety by moving from a regulatory regime to that of a safety culture with a strong emphasis on the human element. Among its goals the requirements are indicating to promote and communicate, through human element principles, a maritime safety culture and heightened marine environment awareness and to provide a framework to encourage the development of non-regulatory solutions and their assessment, based upon human element principles. Thus today, all IMO Committees are instructed to consider the human element when developing new or amending existing performance standards.

Much of this change has been brought about by the Joint MSC/MEPC Working Group on the Human Element. The Group has also been directly involved in the development of the ISM Code, the guidelines on fatigue, and of the Human Element Analysing Process (HEAP). HEAP is a practical and non-scientific checklist to assist regulators in ensuring that all the human element aspects related to the ship and its equipment, and the master and his crew, have been taken into consideration when introducing or amending IMO instruments.

Two recent updates to SOLAS clearly demonstrate IMO's change in direction from a regulatory regime to that of a safety culture with a strong emphasis on the human element. Chapter II-2 (Construction - Fire protection, fire detection and fire extinction); part E deals exclusively with human element matters such as training, drills and maintenance issues, and part F sets out a methodology for approving alternative designs and arrangements. Chapter V-15 features the decisions that affect bridge design, the design and arrangement of navigational systems and equipment on the bridge and bridge procedures. Bridge Resource Management, information processing and decision-making, workload, human error, fatigue and distraction, together with clarity of controls, alarms, displays and status indication are all addressed. Indeed in the light of the development of Chapter V-15, there is a feeling that the scope of the regulations should be widened, to encompass everything that could influence the watchkeeper's function on the bridge.

The requirements of the relevant IMO performance standards for the Electronic Chart Display and Information System (ECDIS), radar, plotting aids, Automatic Identification System (AIS), Integrated Bridge System (IBS) and

Integrated Navigation System (INS) have caused serious human-system interface problems, in terms of the integration and presentation of navigation related information on the bridge. These problems are, however, being addressed by the International Electro-technical Commission (IEC) on behalf of the IMO.

5 Conclusions

The importance of knowledge should not be underestimated, but it must be applied to the real world at some point, and it would be beneficial to give the authorities and mariners some guidelines on how this knowledge can be used, instead of providing theoretical models.

According to the UK P&I Club, human error costs the maritime industry $541m a year [10]. From their own analysis of 6091 major claims (over $100,000) spanning a period of 15 years, the Club has established that these claims have cost their members $2.6bn, 62% of which is attributable to human error. In its loss prevention work, the Club is placing a much greater emphasis on pinpointing root causes in respect of personal injury and other incidents. It recognises that investigators often identify the persons most responsible for incidents (active failures) without uncovering the underlying factors (latent failures).

While the human factor issues are discussed among the stakeholders of the maritime industry, several definitions are used to define the aspects of human interacting with a ship and her equipment. In this respect, it might be useful to analyze the true meaning of definitions and this study proposes the literature survey for the true meaning of definitions that can easily be applied by ship management companies while establishing their ship performance analysis based on human factors engineering. On the other hand, this paper proposes a taxonomy for Administrations and ship management companies to sort their obtained data and evaluate the right classification of errors to take relevant pro-active measures in order to prevent re-occurrences of nonconformities and deficiencies.

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