

Identifying the Potential Roles of Design-based Failures on Human Errors in Shipboard Operations

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ABSTRACT: Despite the various developments in maritime society, human errors have been continued to be one of the primarily causes of marine accidents. The outcomes of detailed investigations on the root causes of human errors can provide valuable support on execution process of required precautions on board merchant ships. This paper examines the potential role of the design-based failures in shipboard systems on human errors during operational process. After completing the statistical research on maritime accidents, the paper concentrates on the Human Factors Analysis and Classification System (HFACS) and the model is supported with the illustrative cases related to the influences of design-based failures on human errors. Consequently, this study originally proposes integrated unit into the HFACS systematic to manage to identify design-based human errors in maritime casualties. The model is eagerly expected to provide additional contributions on identifying the influences of poor design and constructional failures on human errors.

1 INTRODUCTION AND MOTIVATION

As the collective results of technological developments and motivations of the international authorities, it is succeeded in sustaining of decreasing trends in maritime accidents. However, the number of casualties are not still managed to reach the desired level. The impact of the damages, caused from maritime accidents, have been varying such as loss, death, injury, environmental catastrophe, and disasters (Hansen et al. 2002); hence, major parts of the maritime society such as environmental organizations, insurers, classification societies, port state authorities also concentrate on this issue. The changes in the rate of accident statistics and objective evidences of claim analyses have been utilized to make a detailed investigations and to monitor the existing situation regarding with the problem. The scopes of statistical researches are determined to investigate data in both worldwide and regional.

Collisions and groundings were outlined as common incidents according to the outcomes of the statistical research of the United States Coast Guard (USCG, 2004) and the financial impacts were underlined. Another organization, the UK Marine Accident Investigation Branch (MAIB), was emphasized human error as dominant factor in the majority of maritime accidents (MAIB, 2000). As a regional study, Maritime Safety Authority of New Zealand is published the results of statistical data on accidents in the time interval of 1995-1996 (Maritime Safety Authority of New Zealand, 1995-1996). According to the outcomes of synthesis, 49% of shipping incidents are regarding with human factors, while only 35% cite technical factors, and 16% of them regarding with environmental factors. As a very recent investigation, statistics were released by The Transportation Safety Board (TSB, 2006) of Canada. Reports illustrate that shipping accidents, which comprised 90% of marine accidents, reached 419 in 2006, down from 444 in 2005 and from the five-year average of 455. In 2006, marine fatalities totaled 18, down from both the

2005 total of 20 and the 2001-2005 average of 25. On the other hand, analysis and discussions on the statistical reports have been performed within various studies (Esbensen et al 1985; Wagenaar & Groeneweg 1987; UK P&I, 1997; Rothblum, 2000, O'Neil, 2003, Darbra & Casal 2004) in literature.

Existing analyses on statistical data are clearly indicates that human error is still continue to be the most critical factor in maritime accidents. In addition, the investigations on reducing the human error in maritime accidents have been continued eagerly both in industrial base and academic field. Parallel to the distribution of the main causes of maritime accidents, it can be recognized as an effective approach to investigate the root-causes of the human error in maritime accidents.

The urgent needs on solving of human-related errors in ship operations are outlined to increase the motivation on this research. The remains of the paper are organized as follows: Section 2 reviews the taxonomies on the root causes of maritime casualties; in addition, human error evaluation models are introduced. The Human Factors Analysis and Classification System (HFACS) are determined to structure an evaluation model and the evaluation stages are originally interlinked with the illustrative examples on human errors and maritime casualties in Section 3. Additional unit are integrated into the existing evaluation model based on HFACS to be able to investigate the influences of design and installation of system on human error. This paper is concluded with discussing of the originality and expected contributions of the integrated model on examining human errors and expressing the significance and methodology of managing of group consensus between investigators as further research.

2 TAXONOMIES ON HUMAN ERROR IN MARITIME ACCIDENTS

Human error has been cited as a cause or contributing factor in maritime accidents in many of the studies in literature (Hetherington et al. 2006). For identifying the potential role of the human error in casualties, the syntheses on the statistical data and the relevant casualty reports, have been performed in existing studies, are reviewed. As a result of their analysis, Esbensen et al. (1985) argue that the actual figure of incidents involving human error may be as high as 80%. Wagenaar and Groeneweg (1987) analyzed 100 accidents heard by the Dutch Shipping Council between 1982 and 1985, and determined to only 4 of them occurred with no human error causes. Examining the data of Major Hazard Incident Data Service (MHIDAS), human factors were cited in 16% of all in port accidents by Darbra

& Casal (2004). Based on Baker & McCafferty (2005), human error was primarily responsible for approximately 46% of maritime accidents. Engineering failures, weather related failures, and material failures, with the percentage of 41%, 11%, and 2% in a correspondence manner, are recognized as other top level failures by considering United States Coast Guard (USCG) database over the period 1991 to 2001. The outcomes of the various evaluations on the maritime accident reports are reviewed in this section. As a general tendency of the researchers, human error continues to be a dominant factor in approximately 80 to 85% of maritime accidents.

Much more effort on investigating the causes of human error is required to clearly identify the preventive actions and urgent precautions. For investigating the root causes of shipboard accidents, the complexity of the issue increases due to the complicated systems, components, and various user interfaces. The operational requirements of technical system and social environment of crewmembers onboard ships should be considered as significant points of the human error analysis. The scope and complexity of the problem is addressed utilizing of systematic evaluation methodology to manage the effective analysis and applicable outcomes on reducing human error in maritime accidents. As understanding the main causes of the human errors in accidents, a number of human error models and frameworks have been developed and cited by various authors (Edwards 1972; Rasmussen 1982; Wickens & Flach's 1988; Reason 1990; Moray 2000; O'Hare 2000; Wiegmann & Shapell 2001a). Table 1 illustrates the results of bibliographic survey on human error analysis model.

Table 1. Human error evaluation models

Model	Author(s)
SHEL model	Edwards, (1972)
Skills rules- knowledge model	Rasmussen (1982)
Four-stage information processing model	Wickens & Flach (1988)
Generic Error Modeling System (GEMS)	Reason (1990)
Socio-technical model	Moray (2000)
Wheel of Misfortune	O'Hare (2000)
HFACS	Wiegmann & Shapell (2001)

After introducing the existing model, it is determined to refer in this paper to The Human Factors Analysis and Classification System (HFACS), based on Reason's (1990a, b) model of latent and active failures, for designing an evaluation system on maritime accidents and related causes.

HFACS is a general human error framework originally developed as a tool for investigating and analyzing the human causes of aviation accidents (Shappell & Wiegmann 2001; Wiegmann & Shapell 2001b; Wiegmann and Shappell, 2003). HFACS model utilizes to describe human error at each of four levels of failure: unsafe acts of operators, preconditions for unsafe acts, unsafe supervision, and organizational influences. Recently, successful applications of HFACS approach have been performed in U.S. Navy, Marine Corps, Army, Air Force, and Coast Guard for use in aviation accident investigation and analysis.

Table 2 illustrates the major components of the HFACS by categorizing the each elements of the model. For managing the implementation of the HFACS on special cases, additional definitions are required to clearly state the scope of the model. The outputs of the statistical researches, widely discussed in previous sections, can be utilized to perform the model on maritime casualties. Data of the statistical researches are distributed on the related factors and priority weights of them are computed to identify the primarily causes of human errors.

Table 2. General framework of the HFACS

HFACS - Major Components	
Unsafe Acts	
➤ Errors	
<input checked="" type="checkbox"/> Skill-based errors	
<input checked="" type="checkbox"/> Decision errors	
<input checked="" type="checkbox"/> Perception errors	
➤ Violations	
<input checked="" type="checkbox"/> Routine violations	
<input checked="" type="checkbox"/> Exceptional violations	
Pre-conditions for unsafe acts	
➤ Substandard conditions of operators	
<input checked="" type="checkbox"/> Physical/Mental limitations	
<input checked="" type="checkbox"/> Adverse physiological states	
<input checked="" type="checkbox"/> Adverse mental states	
➤ Substandard practices of operators	
<input checked="" type="checkbox"/> Crew resource mismanagement	
<input checked="" type="checkbox"/> Personnel readiness factors	
Unsafe Supervision	
➤ Inadequate supervision	
➤ Planned inappropriate supervision	
➤ Failed to correct problem	
➤ Supervisory violations	
Organizational influences	
➤ Inadequate resources management	
➤ Organizational climate	
➤ Organizational process	

3 STRUCTURING OF HFACS ON HUMAN ERROR IN MARITIME ACCIDENTS

3.1 General Overview on Application Requirements

For implementing the HFACS structure on identifying the human error, it is required to define the causal categories in the level base such as unsafe acts of operators, preconditions for unsafe acts, unsafe supervision, and organizational influences. The investigators, who are examining the accident scenarios, are considering the classification scheme on supporting their judgments on the case.

The evaluation items on unsafe acts is generally concentrates on the nature errors of the human beings. The crewmembers on board are the potential candidates to cause unexpected casualties onboard. Hence, in the initial stage of the evaluation, the investigator should decide that the origin of the situation based on error or violence. Improper checking of barometer device as a skill based error, wrong response on emergence fire alarms as a decision error, and misjudged on distances during voyage as a perceptual errors can be expressed as sub-categories of skill-based errors. Furthermore, failing to adhere to safety maneuvering procedure as a routine violence, and unauthorized anchoring during voyage as an exceptional violence are illustrated as sample cases on violations.

Preconditions for unsafe acts are another category for identifying the roles of human errors in accidents. The investigators mainly concentrate on the question that why the unsafe acts took place. Mental and physiological fatigue, medical illness, failed to coordinate hierarchy on board can be illustrated as a couple of example for this unit.

Unsafe supervision is much more related to coordination and executive activities within the operational process. Failed to provide training, improper manning on board ships, failed to managing corrective action strategy, assigning unqualified personnel on board, scheduling personnel rest hours inadequately can be illustrated as sample cases regarding with the unsafe supervision.

Finally, organizational influences are investigated and the role of the organizations on poor supervisory facilities is expected to be outlined. Conditions of the equipments, availability of communication opportunities, satisfaction of policies and procedures, risk management and safety related programs, are determined as the focusing themes during accident analyses.

3.2 Integrated Unit Proposals on Structuring HFACS

Despite it is relatively considered within the level of organizational influences as equipment and facility resources, there are also additional needs on expressing influences of operational requirements and system characteristics on human error. Therefore, specifications and complexity of the technical system are required to examine the related operational constraints such as maintainability, ergonomics, safety, technology, and automation on board ships as well. Enhancing the shipboard working environment such as managing user interfaces, motivating on working conditions such as noise, vibration, ventilation, lighting, temperature, and air quality are addressed as primarily issues regarding with improvement of shipboard systems in manner of ergonomics and human factor. On the other hand, repairing and maintenance facilities, performed onboard ships, are the significant activities. The impacts of technological improvements and automation in system level on human error in maritime casualties should also be considered as another critical factor.

Additional unit can be integrated into the model to clearly identify the human errors that are caused by hardware in terms of ship's systems and components. Table 3 illustrates the relevant items that are required to be able check the influences of system and operating conditions on human error in maritime accidents.

Table 3. Integrated unit into HFACS structure

HFACS - Integrated Unit	
Hardware	
➤ Ergonomics	
<input checked="" type="checkbox"/> Design and installation	
<input checked="" type="checkbox"/> Working environment	
<input checked="" type="checkbox"/> User interfaces	
<input checked="" type="checkbox"/> Human fatigue	
➤ Maintenance facilities	
<input checked="" type="checkbox"/> Maintenance procedures	
<input checked="" type="checkbox"/> System maintainability	
<input checked="" type="checkbox"/> Workspace conditions	
➤ Technology and Automation	
<input checked="" type="checkbox"/> Complexity	
<input checked="" type="checkbox"/> Training needs	
<input checked="" type="checkbox"/> Technical support	

4 CONCLUSION AND DISCUSSIONS ON FURTHER ISSUES

Application requirements of the HFACS, systematic approach for investigating human errors, on investigating influences of system related failures on

human error in maritime accidents are outlined in this paper. The human errors are cited in previous studies in literature as the most focusing factor in maritime accident; therefore, the model is expected to provide original contributions on investigating the potentials of human factors in marine casualties successfully. In addition, the paper proposed integrating unit, including the evaluations on ergonomic requirements, maintenance facilities, and technology and automation levels of the system, into the HFACS to be able to manage to identify design-based human error in maritime accidents. The influences of lacking of ergonomics requirements, maintainability, and integration of technology and automation into systems onboard ships can be examined deeply by utilizing integrated model unit. Therefore, the roles of poor system design and constructional failures on human error can be clearly identified in detail in applications on real cases regarding with onboard ships. The various systems in different levels of complexity, sub-systems, and components in ship machinery systems, user interfaces in both engine room and bridge can be recognized as the hardware elements of the ships. Hence, the scope of the investigations on human errors in maritime accidents can be extended in system level by utilizing the proposed methodology as well.

As practical application, the original model can be performed on a set of data and accident reports to be able to obtain illustrative results. The outcomes of the HFACS based analysis with the additional integrating unit on maritime accidents provide to identify the potential roles of the system based failures on human errors quantitatively. In advance, integrating of the group decision methodology on determining judgements with more than one investigator in a group consensus can be assigned as a further research proposal to increase the consistency of the HFACS mechanism.

REFERENCES

- Baker C.C. & McCafferty D.B. 2005. Accident Database Review of Human-Element Concerns: What do the results mean for classification?, Human Factors in Ship Design, Safety and Operation, 23-24 February, London.
- Canadian Transportation Safety Board. 2006. Preliminary Transportation Occurrence Statistics 2006, Canada.
- Edwards E. 1972. Man and machine: systems for safety. In: Proceedings of British Airline Pilots Association Technical Symposium. British Airline Pilots Association, London, UK: 21-36.
- Esbensen P., Johnson R.E. & Kayten P. 1985. The importance of crew training and standard operating procedures in commercial vessel accident prevention. Paper presented at the Tenth ship technology and research (STAR) symposium, Norfolk.

- Hansen H.L., Nielsen D. & Frydenberg M. 2002. Occupational accidents aboard merchant ships. *Occupational & Environmental Medicine*, 59 (2): 85–91.
- Hetherington C., Flin R. & Mearns K. 2006. Safety in shipping: The human element. *Journal of Safety Research*, 37 (4): 401–411.
- Maritime Safety Authority of New Zealand. 1995–1996. *Maritime accidents*.
- MAIB 2000. Annual report 1999. London: Department of the Environment Transport and Regions.
- Moray, N. 2000. Culture, politics and ergonomics. *Ergonomics*, 43 (7): 858–868.
- O'Hare D. 2000. The “wheel of misfortune”: a taxonomic approach to human factors in accident investigation and analysis in aviation and other complex systems. *Ergonomics*, 43 (12): 2001–2019.
- O'Neil, W. A. 2003. The human element in shipping. *World Maritime University Journal of Maritime Affairs*, 2(2): 95–97.
- Rasmussen, J. 1982. Human errors: A taxonomy for describing human malfunction in industrial installations. *J. Occup. Accid.* 4: 311–333.
- Reason J. 1990a. *Human error*. Cambridge University Press. New York.
- Reason J. 1990b. The contribution of latent human failures to the breakdown of complex systems. *Philos Trans R Soc Lond B Biol Sci*, 327: 475–484.
- Shappell S.A & Wiegmann D.A. 2001. Applying reason: the human factors analysis and classification System-HFACS. *Human Factors and Aerospace Safety*, 1 (1): 59–86.
- Rothblum, A.R. 2000. Human error and marine safety. Paper presented at the National Safety Council Congress and Expo, Orlando, FL.
- UK P&I Club. 1997. *Analysis of major claims: ten years trends in maritime risk*, London:
- United States Coast Guard. 2004. Fiscal year 2004 report. Retrieved 08/07/04, 2004.
- Wickens C. & Flach J. 1988. Information processing. In: Wiener, E.L., Nagel, D.C. (Eds.), *Human Factors in Aviation*. Academic, San Diego, CA: 111–155.
- Wagenaar, W.A. & Groeneweg J. 1987. Accidents at sea: Multiple causes and impossible consequences. *International Journal of Man-Machine Studies*, 27(5-6): 587–598.
- Wiegmann D.A. & Shapell S.A. 2001a. Human error analysis of commercial aviation accidents: application of the Human Factors Analysis and Classification system (HFACS). *Aviat Space Environ Med*, 72(11): 1006–1016.
- Wiegmann D. & Shappell S. 2001b. A human error analysis of commercial aviation accidents using the human factors analysis and classification system (HFACS). Federal Aviation Administration, National Technical Information Service, N Springfield, VA.
- Wiegmann D. & Shappell S. 2003. *A Human Error Approach to Aviation Accident Analysis: The Human Factors Analysis and Classification System*. Ashgate Publishing Ltd., Aldershot.