Journal of the Korean Society of Marine Engineering, Vol. 40, No. 8 pp. 721~725, 2016
J. Korean Soc. of Marine Engineering (JKOSME)
http://dx.doi.org/10.5916/jkosme.2016.40.8.721

ISSN 2234-7925 (Print)
ISSN 2234-8352 (Online)
Original Paper

A study on maritime casualty investigations combining the SHEL and Hybrid model methods

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(Received September 29, 2016； Revised October 25, 2016；Accepted October 25, 2016)

Abstract: This paper reviews the analysis of a given scenario according to the Hybrid Model, and why accident causation models are necessary in casualty investigations. The given scenario has been analyzed according to the Hybrid Model using its main five components, fallible decisions, line management, psychological precursors to unsafe acts, unsafe acts, and inadequate defenses. In addition, the differences between the SHEL and the Hybrid Model, and the importance of a safety barrier during an accident investigation, are shown in this paper. One unit of SHEL can be linked with another unit of SHEL. However, it cannot be used for the analysis of an accident. Therefore, we must use an accident causation model, which can be a Hybrid Model. This can explain the "How" and "Why" of accident, so it is a suitable model for analyzing them. During an accident investigation, the reason we focus on a safety barrier is to create another safety barrier or to change an existing safety barrier if that barrier fails. Hence, the paper shows how a sea accident can be investigated, and we propose a preventive way of avoiding the accident through combining the methods of different models for the future.

Keywords: Hybrid model, Casualty investigation, SHEL, Safety barrier

1. Introduction

According to research by TSB Canada, Cormier, the UK P&I Club, and Bryant, most maritime accidents are caused by human factors **[1]**. The reason why we focus on human factors during an incident investigation is that humans are at the core of what happens **[2]**. Furthermore, even though the human element is at the root of the majority of such occurrences, most casualties obviously have arisen as a result of poorly designed or improperly maintained equipment combined with the human element of unsafe acts **[3]**. Therefore, we mainly concentrate on two aspects, human factors and technical issues, as a cause of incidents.

A SHEL model focuses on one specific person with four surrounding elements, which are software, hardware, environment ware, and other liveware, as described by Hawkins **[4]**. This model has limitations to explaining an entire accident because it just describes the "where," "what," and "who" about it. Investigators need other specific types of casualty investigation to learn about the "how" and "why." Using the Hybrid Model to investigate accidents can be useful for discovering the appropriate cause as it relates to the "how" and "why." After a marine accident, we usually have to investigate the ship to find specific causes. Furthermore, relevant investigation expertise is used to assess the accident in terms of a safety analysis, and recommendations are made to guard against future incidents based on four aspects, the enforcement aspects, regulatory aspects, educational aspects, and safety scientific aspects **[5]**. In my opinion, these four aspects can amount to one type of safety barrier. At the end of a casualty investigation, the creation of a safety barrier is the most important step as a final complementary measure.

In this sense, this paper mentions the analysis of the given scenario according to the Hybrid Model and why accident causation models are necessary in casualty investigations. In addition, the differences between the SHEL and the Hybrid Model, and the importance of a safety barrier during an accident investigation, are shown in this paper.

2. Analysis of the occurrence according to the Hybrid Model

James Reason's Hybrid Model is made up of fallible decisions, line management deficiencies, psychological precursors of unsafe acts, unsafe acts, and inadequate defenses, as shown in **Figure 1 [6]**.

This paper analyzes the MV Happy Sailor accident

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according to each of the five elements of James Reason's Hybrid Model. For an accident to happen, all five elements of the Hybrid Model have to be affected by one factor. In other words, if any element works perfectly or at no stage has no faults, no accident can occur. In addition, the five elements have to be linked with each other for the accident to occur. If each element has many faults, it creates more possibilities for an accident to happen. The relevant faults of each element are linked with each other, and eventually the accident occurs. Decision-makers, line management, and the psychological precursors of unsafe acts are in a latent state, but the level of the unsafe act can be an active failure. However, the defense level includes both active and latent failures.

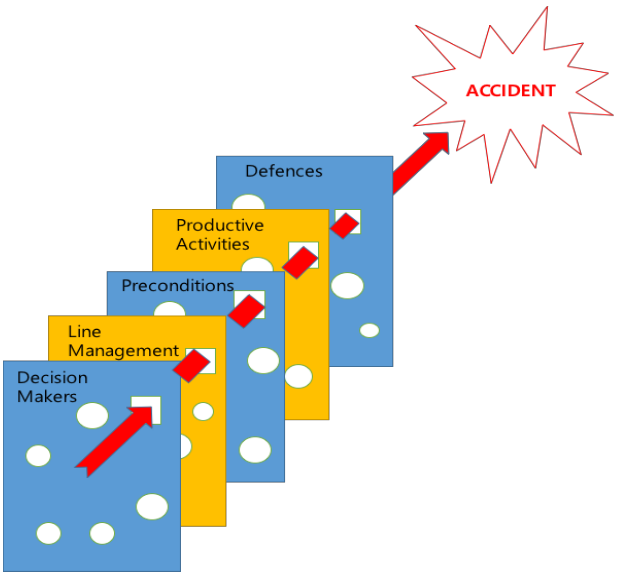

Figure 1: Hybrid Model

2.1 Fallible decisions

In this section, top management is analyzed as a decision-maker. Management bought the MV Happy Sailor when the shipping company was in financial difficulty. Management was under time pressure to make money due to its economic problems, so the ship had to be engaged in voyages urgently for it to be productive. Decision-makers always have to choose between safety and productivity according to Reason **[6]**. In this case, the shipping company put less emphasis on safety because of its focus on money. Its decisions can be directly linked to the line management.

2.2 Line management

The line management comprises the captain, the technical department manager, and the chief engineer, who are in charge of implementation of decisions in terms of its three components, maintenance, operations, and training **[6]**. If the line management has deficiencies, it may increase the accident potential of managerial decisions **[7]**.

2.2.1 Maintenance

The technical department had not repaired the ship properly and had not prepared a manual for emergency situation. In addition, they were not familiar with the ship. The reason why the line management did not have a manual to prepare for an emergency was that the top management was under economic pressure.

2.2.2 Training

Training should be explained through its implementation by the line management. The technical manager and the captain had not taught 50% of the crew any firefighting course on board or shore side. A total of 45% of the service crew had little experience of training about the passenger ship by line management in terms of safety. Junior officers were not familiar with the ship: The technical department and the captain had not trained the officers on the special procedures and protocols of the company. Crewmembers should have been trained on how to launch the lifeboat by the captain on board ship.

2.2.3 Operations

The captain's decision to implement the policy of the decision maker is a line management one. If the captain did not provide any firefighting training, it means that he was not competent to operate the ship in case of an emergency. In terms of response and the process of the ship's accident, he did not take action or engage in any appropriate behavior to extinguish the fire and did not organize a firefighting team. Moreover, he initially should have pushed the fire emergency alarm to inform the passengers about the fire instead of pushing the general alarm. As a line manager, he left the ship without making any decision about controlling the situation.

2.3 Psychological precursor of unsafe acts

Jacques discussed the importance of psychological precursors in his work, noting that accident analysis needs psychological expertise and knowledge about relevant models of human decision-making **[8]**. Each precursor leads to a large number of unsafe acts depending on the prevailing conditions. In addition, many of the precursors mainly come from the human condition at this level, such as their stress, fatigue, or general health **[6]**. Everything relating to this level exists prior to the unsafe act. The crew becomes a source of unsafe acts. For instance, if we take into consideration the qualifications of the captain, who had not worked for the previous 20 years as a seafarer, he could have had problems in terms of maintaining a proper workforce to operate the passenger ship. Furthermore, we can guess that the captain was poorly motivated and not knowledgeable about modern work practices. In addition, the crewmembers and officers may have been too tired to prepare for or to start the voyage at short notice, so they would not have been able to properly control the situation when the accident occurred. Crewmembers from 25 different countries do not constitute a good workforce on one ship because they cannot communicate appropriately with some passengers. This fact led to further problems. A delay experienced when the lifeboats launched, and the crew did not respond adequately to the passengers' questions.

2.4 Unsafe Act

With due regard to the unsafe act to "What was doing at that time," "What is done?" in terms of physical act. According to James Reason, an unsafe act can only define by relating to the presence of a particular hazard and is more than an error or violation **[6]**. Because of the nature of human error, we cannot eliminate the unsafe act. The captain closed the fire control door without confirming whether there were people in the passengers' cabins or corridors, and at the same time, did not confirm where the origin of the fire was. And if he had wanted to close those doors, he could have closed firstly the fire control door on deck three or could have closed all the fire control doors after he confirmed the origin of the fire and everybody had escaped from those areas. Moreover, he instructed the watch officer to close the air ventilation without having any information of where the source of the fire was. Many people died due to increased levels of carbon monoxide and hydrogen cyanide. The fire detection panel had a faulty alarm, and someone put off the line of the system before the accident. This activity itself constitutes an unsafe act.

2.5 Inadequate defenses

Defense plays a significant role in providing protection for such an accident. A sprinkler was not working in the corridor on deck three. Although a smoke detector was installed, the watch officer could not find the origin of the fire due to the fire detector panel being offline. The fire alarm sounded for only one minute and was not very loud. If the fire alarm had sounded for longer, many more passengers would have recognized that there was a fire and could have escaped from their cabins to a safe place. Some training itself belongs to the level of defense even if it takes a comparatively long time The company should have carried out certain firefighting courses with the captain, provided a familiarization course for such a passenger ship to the 45% of crew members who had received little training, and given a company familiarization course to the junior officers. The flag state of the ship had not carried out any surveys or issued all the certificates required. If the flag state had surveyed the ship properly in accordance with international regulations, such an accident would not have happened.

3. Necessity of Accident Causation Models

According to Hollnagel's principle of forward causality, "If we know what the cause is, then we can look for the effect," and "If we see what the effect is, then we can find out what the cause is." He highlighted that "the 'constant' accident model is made up of technology, equipment, human performance, and organization" and "if something happens, then there must be a cause" **[9]**. Therefore, we need accident causation models in casualty investigations. Accident causation models can divide into sequential, epidemiological, and systematic models, as noted by Hollnagel **[9]**. The analysis goals of the sequential model are to eliminate or contain causes, epidemiological models create stronger defenses and barriers, and systemic models monitor and control performance. However, I want to highlight, in particular, the sequential model and the epidemiological accident model in terms of a clear cause and effect **[9]**. Accordingly, we can assume the consequence to be predictable by using an accident causation model. It focuses on how accidents happen and how they can be avoided while investigators are finding out the causes of such accidents **[10]**. The administrations that investigators serve usually concentrate only on how lessons can be learnt from an accident and which regulations are needed to prevent a similar type of accident recurring. The aim of an accident investigation is to collect appropriate data and to examine risk assessments. We therefore identify the patterns and trends of previous accidents, and we can implement good alternative measures or create corrective actions to prevent certain accidents for the near future. Moreover, accident investigations usually are a high priority task because of the need to learn from accidents in order to avoid similar ones in the future.

4. Necessity of Accident Causation Models

A 21/Res.884 of the IMO introduces the SHEL and the Hybrid Model (Reason) in order to provide assistance when the human error effect on maritime casualties is being investigated **[5]**. As shown in **Figure 2**, SHEL is a simple model describing the interactions of human operators in technical systems. The main purpose of the model is to create an understanding of four types of human interactions in the system and to support the interrelationship between those work systems. It consists of software, hardware, environment, and other liveware. A liveware component is at the center of the analysis, and the investigator looks at how it interrelates with the surrounding four types of interactions within technical systems. In this respect, this model can be used to provide guidance on where to look for evidence, so it helps on the "who," "where," and "what." However, the Hybrid Model focuses on the "How" and "Why."

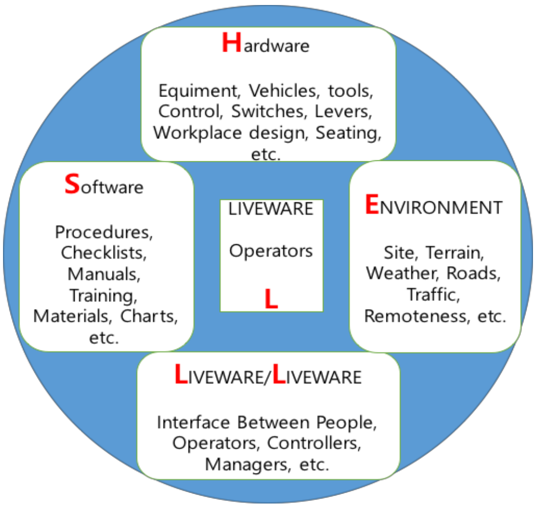

Figure 2: SHEL model

These models have a totally different focus and therefore cannot be compared. The SHEL Model includes simple performance shaping factors. SHEL focuses on one person in the system, which is also how one uses the system. The examination focuses on a specific person and the interactions of that person in the system are analyzed.

When the analysis starts in an accident investigation, relevant evidence is collected at once. At this time, we can see the limitations of SHEL. The SHEL Model has an advantage in providing an overview about different types of interactions of people in technical systems; however, it cannot contribute much to the analysis of these interactions. In order to analyze an accident, different models are used, so it is called accident causation models **[5]**.

Reason's Hybrid Model is an epidemiological model focusing on conditions leading to an accident **[5]**. It can be used for all types of accidents. Focusing on conditions leading to an accident means in this context that the model is looking primarily from an organizational point of view at accidents. The Hybrid Model is more suitable for analysis. It is based on Reason's model of production and is made up of five components, the decision-maker, line management, the psychological precursors of unsafe acts, unsafe acts, and defenses. These five elements are connected with each other. Furthermore, the decision-maker affects the other four elements, so the model can focus on how inadequate decisions influence the environment of the ship in which accidents can develop. The model is much more complex than the SHEL one. It is not focused on one specific person like SHEL. The Hybrid Model considers management impact on a technical system prior to the accident and mainly examines how the accident happened and why it occurred. Therefore, if the defenses compromised together with another step, an accident can happen.

5. Necessity of Safety Barriers

Hollnagel states that the role of a safety barrier is to prevent an incident from taking place and reduce the effect of the consequences if it happens **[9]**. The reason why investigators concentrate on barriers during accident investigations is to find clear causes and to generate certain protections as a preventive measure in the future.

Module 6 of the IMO's e-learning: Maritime Accident and Incident Investigators states, "We have analysed whether or not there are defences in the system that would prevent the events from causing the assessed severe consequences. Accidents happen as a result of insufficient defences." A safety barrier is composed of physical or material barrier systems, functional barrier systems, symbolic barrier systems, and incorporeal barrier systems according to Hollnagel **[9]**.

Four types of safety barrier need to be described. First, physical or material barrier systems physically prevent actions from being carried out. Examples include a fence or hand rail. Second, a functional barrier system works by impeding the action to be carried out. Examples are a physical interlocking system and sprinklers. Third, "A symbolic barrier system works indirectly through its 'meaning', and hence requires an act of interpretation by someone," such as signs, signals, warnings, alarms, procedure, and labels. In case of the MV Happy Sailor accident, there was a lack of fire alarms, which meant many passengers did not notice the sound. In addition, because there was no low light system in the corridors on board the ship, many people could not find the exits to escape from inside the ship. Fourth, "an incorporeal, or non-material, barrier system also requires interpretation and furthermore relies on the acting person to recognize its existence in the first place," such as ethical norms or group pressure, and rules or laws **[9]**. At that time, there were no regulations regarding firefighting and prevention requirements, such as non-combustible materials. If some regulations that SOLAS require regarding firefighting existed at that time, many fatalities would not have occurred on the ship. Therefore, a casualty investigator should focus on the causes of the accident, and they have to devise a safety barrier to prevent such accidents occurring in the future. A safety barrier is created as a complementary measure in the final step. Someone might say that the same accidents never recur. Moreover, every accident's cause can be different, depending on the situation. Hollnagel comments on the cynical responses to the need for safety barriers, stating "our whole moral or ethical code requires that cause must be found and responsibility assigned," "the analysis may reveal weakness in the system," and accidents happen due to an unexpected combination of common factors **[9]**.

6. Conclusion

The given scenario was analyzed according to the Hybrid Model's five main components, fallible decisions, line management, the psychological precursor of the unsafe act, the unsafe act, and inadequate defenses. The decision-maker is the main manager in the organization and always must take into consideration the balance between safety and productivity. If a decision-maker determines the wrong policy, it affects directly the line management and influences the other three elements as well. The line management, which includes the captain, chief engineer, and technical management, implements certain strategies of the decision-maker in terms of maintenance, operation, and training. The psychological precursors of unsafe acts mainly come from potential human conditions, such as stress, fatigue, and ill-health. Fallible decisions, line management, and the psychological precursor of the unsafe act exist in a latent state. The unsafe act based on active failure is a physical action itself that occurs in accidents. The defense level, which is based on active failure and latent failure, can prevent an accident as a final step. If the defense fails, an accident occurs. The reason we need accident causation models is that after accident investigations, we can learn the cause of the accident from the models. We can therefore implement alternative measures to prevent an unexpected accident in the future. SHEL stands for Software, Hardware, Environment, and Liveware. The main liveware is located at the center, between the above-listed over four elements. It can help the "what," "where," and "who" in the explanation to be found in the technical system. One unit of SHEL can be linked with another unit of SHEL, but it cannot be used for the analysis of an accident. We must therefore use an accident causation model, of which one is the Hybrid Model. It can explain the "How" and "Why"; so, it is a suitable model to analyze an accident. During an accident investigation, the reason we focus on the safety barrier is to create another safety barrier or to change the existing safety barrier if that one fails.

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