Applying the AcciMap methodology to investigate the tragic Sewol Ferry accident in South Korea

Samuel Lee, Young Bo Moh, Maryam Tabibzadeh, Najmedin Meshkatia

Daniel J. Epstein Department of Industrial & Systems Engineering, University of Southern California, 3715 McClintock Ave., GER240, Los Angeles, CA 90089, USA

Department of Manufacturing Systems Engineering & Management, California State University, Northridge, 18111 Nordhoff St., JD4510, Los Angeles, CA 91330, USA

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Abstract

This study applies the AcciMap methodology, which was originally proposed by Professor Jens Rasmussen (1997), to the analysis of the tragic Sewol Ferry accident in South Korea on April 16, 2014, which killed 304 mostly young people and is considered as a national disaster in that country. This graphical representation, by incorporating associated socio-technical factors into an integrated framework, provides a big-picture to illustrate the context in which an accident occurred as well as the interactions between different levels of the studied system that resulted in that event. In general, analysis of past accidents within the stated framework can define the patterns of hazards within an industrial sector. Such analysis can lead to the definition of preconditions for safe operations, which is a main focus of proactive risk management systems.

In the case of the Sewol Ferry accident, a lot of the blame has been placed on the Sewol’s captain and its crewmembers. However, according to this study, which relied on analyzing all available sources published in English and Korean, the disaster is the result of a series of lapses and disregards for safety across different levels of government and regulatory bodies, Chonghaejin Company, and the Sewol’s crewmembers. The primary layers of the AcciMap framework, which include the political environment and non-proactive governmental body; inadequate regulations and their lax oversight and enforcement; poor safety culture; inconsideration of human factors issues; and lack of and/or outdated standard operating and emergency procedures were not only limited to the maritime industry in South Korea, and the Sewol Ferry accident, but they could also subject any safety-sensitive industry anywhere in the world.

1. Introduction

Accidents in complex socio-technical systems are the result of a loss of control over hazardous work processes, which can cause injuries to people, loss of investment, or damage to the environment (Rasmussen, 1997; Rasmussen et al., 1994).

Over the years, a large number of accident investigation methodologies have been developed to analyze a wide range of domains and capture the increasing complexity of those domains. In this paper, the main focus is on the analysis of safety-critical systems. These systems are typified by several main characteristics. First, the technology they use changes very rapidly at the operative level (Rasmussen and Svedung, 2000). Second, they have complex interactions resulting from unfamiliar or unexpected sequences of events that are often either imperceptible or not immediately comprehensible (Wang, 2008). Third, the propagation of an accidental course of events in these systems “is shaped by the activity of people which either can trigger an accidental flow of events or divert a normal flow. Safety, then, depends on the control of work processes so as to avoid accidental side effects causing harm to people, environment, or investment” (Rasmussen, 1997, p.184).

The investigation of major accidents in safety-critical systems reveals a variety of contributing factors, both from within involved organizations and from dysfunctional interactions between them in a broader perspective. Based on this analysis, accidents do not occur as the act of an isolated individual or a front-line operator, but due to highly interactive and collective processes as well as the influence of involved decision-makers in all relevant levels of society (Le
Coze, 2015; Trotter et al., 2013, 2014). As a result, there is a need for accident investigation frameworks that integrate the analysis of contributing factors from different parts of a socio-technical system with interactions between them.

There have been several developed methodologies to better understand and analyze accidents. Some examples of these methodologies include the systems-theoretic accident model and processes (STAMP) by Leveson (2004, 2011), Reason’s model of organizational accidents (1997) and Rasmussen’s AcciMap approach (1997). Rasmussen’s AcciMap approach is particularly useful for this purpose as it models different contributing factors of an accident, and their interactions, in a causal diagram.

One example of catastrophic events in safety-critical systems is the Sewol Ferry accident. On April 16, 2014, Sewol Ferry, the South Korean ship carrying 476 passengers from Incheon to Jeju Island, sank disastrously. The 18-year-old Japanese-built ship was purchased by a company named Chonghaejin, which added two more floors to the ship to hold more passengers, making the ship extremely unstable (해양안전관리원 특별조사부, 2014). During the voyage, when the ship made a sharp turn, it lost its balance and started to list. When the captain Jun Seok Lee communicated with the Vessel Traffic Service (VTS) for help, the captain made questionable decisions such as telling the VTS that the passengers could not evacuate and instructing the passengers to stay on board (해양안전관리원 특별조사부, 2014). By the time the captain finally told everyone to evacuate, it was too late. At that time, he uncustomary had already left the ferry. As the result of this accident, 304 people, who were mostly high school students, lost their lives in what is considered to be one of the most tragic maritime accidents in the history of South Korea.

This paper applies the AcciMap methodology for the analysis of the Sewol Ferry accident by investigating different contributing causes of that accident as well as the interactions between them. It is noteworthy that although the AcciMap framework has been utilized to analyze the contributing causes of the Sewol Ferry accident, this is just a case study in this paper in order to highlight the importance and vast applications of this powerful methodology for the analysis of past accidents and the generalization of lessons learned in order to prevent future system failures and catastrophes. The analysis of past accidents within the stated framework can define the patterns of hazards within an industrial sector, which can lead to definition of preconditions for safe operations, as a main focus of proactive risk management systems.

The investigation of this research is based on some main stream media, the Korea Maritime Safety Tribunal Investigation Report as well as our personal communication with scholars and professors in Korea Advanced Institute of Science and Technology (KAIST) of higher educations and Korea Industrial Safety Corporation.

In the scope of this paper, we have followed the spirit of the AcciMap methodology to identify the contributing causes and the involved decision-makers of the Sewol Ferry accident. However, we do not intend to put blame on any entity.

Based on this introduction, the outline of this paper is as follows: Section 2 introduces the Rasmussen’s risk management framework as well as the AcciMap methodology. Section 3 describes in detail our developed AcciMap framework for the analysis of the Sewol Ferry accident. In Section 4, we further discuss the results of analyzing our developed AcciMap framework. Finally, we go through some concluding points in Section 5.

2. Rasmussen’s risk management framework and AcciMap methodology

Rasmussen introduces a 6-layer, hierarchical framework (Fig. 1), known as risk management framework, with each level representing a main group of involved decision-makers, players or stakeholders in a studied system (Rasmussen, 1997). These six levels, from top to bottom, are: government, regulators and associations, company, management, staff, and work. Analysis using this framework not only considers the activities of players in each level but more importantly, the interactions between them, which take the form of decisions propagating downward and information propagating upward (Branford, 2011; Rasmussen and Svedung, 2000; Salmon et al., 2012).

Often “a quite normal variation in somebody’s behavior” can release an accident (Rasmussen, 1997). Also, even if this particular variation is avoided, the accident would very likely be released by another factor in time. One important point of consideration in this regard is to see the actions of workers or the errors that triggered an accident in a broader socio-technical context since those actions are impacted by decisions and activities of other players in all the 6 stated levels of Fig. 1 (Rasmussen and Svedung, 2000; Svedung and Rasmussen, 2002).

The AcciMap methodology was developed by Professor Jens Rasmussen (1997) in conjunction with his 6-layer risk management framework, which was illustrated in Fig. 1. This methodology captures the associated socio-technical factors of an accident within an integrated framework and analyzes the contribution of those factors in causing the accident. This graphical representation is useful in structuring the analyses of hazardous work systems and in identifying the interactions between different levels of decision-makers, which shape the landscape in which accidents may “unfold” themselves (Svedung and Rasmussen, 2002).

It is noteworthy that AcciMap is part of a broader proactive risk management process to develop risk assessment strategies from generalizing the analysis of previous accidents (Branford, 2011). In general, analysis of past accidents within the stated framework can define patterns of hazards within an industrial sector. Such analysis can lead to the definition of preconditions for safe operations, which is a main focus of proactive risk management systems. However, as thoroughly discussed and analyzed by Underwood and Waterson (2014), AcciMap has certain inadequacies, which can be addressed by combining it with other analysis techniques.

This methodology has been used as an independent tool for accident analysis in different domains as well. These applications include chemical processing (CSB Report, 2014, 2015), transportation (Rasmussen and Svedung, 2000; Underwood and Waterson, 2014), aviation (Branford, 2011), public health (Vicente and Christoffersen, 2006), anti-terrorism (Jenkins et al., 2010; Waterson and Jenkins, 2011), gas production (Hopkins, 2000), and most recently, oil and gas drilling (Tabibzadeh and Meshkati, 2015).

In the context of maritime transportation, to our knowledge, the AcciMap methodology has been only applied by Rasmussen and Svedung (2000) to analyze the three accidents of Zeebrugge; capsizing of the roll on/roll off (RORO) Ferry Herald of Free Enterprise, capsizing and wrecking of the RORO Ship Vinca Gorthon in the North Sea, and grounding of gas tanker Balina in Lake Mälaren. This study can be safely considered as the first systemic investigation that also uses the powerful AcciMap framework to analyze a major recent maritime accident, the Sewol Ferry capsizing.

An AcciMap describes failures, decisions and actions at each of the six levels of Fig. 1 through the construction of a causal diagram. In addition, this methodology maps the interrelationships of those levels. In general, the AcciMap diagram is an integrated framework, which provides a big-picture to illustrate the context in which an accident occurred as well as the interactions between different levels of a socio-technical system that resulted in that event (Branford, 2011).

As stated in the introduction section, the AcciMap methodology
has been used for the analysis of the Sewol Ferry accident. The application of this framework sheds light on identifying the main contributing causes of that accident in each of the six levels of the described model in Fig. 1. It also highlights the interactions between involved, key players within those levels. The developed AcciMap framework for the case of the Sewol Ferry accident has been described in the next section.

3. The AcciMap framework of the Sewol Ferry accident

In this section, the AcciMap framework has been utilized for the analysis of the Sewol Ferry accident, which occurred on April 16, 2014, in South Korea. There have been some adjustments to the illustrated risk management framework in Fig. 1 to make the AcciMap specific to the context of our analyzed problem. We have tried to use the same stated terminologies in the developed AcciMap framework by Rasmussen and Svedung (2000) for the analysis of the Zeebrugge Ferry accident in our model due to the similar nature of these two accidents being from the maritime industry.

Our developed AcciMap in this paper, which has been shown in Fig. 2, consists of 6 main layers. In this AcciMap, the first five layers of the framework are: government and legislation, regulatory bodies and associations, company management and local area planning, technical and operational management involved, and accidental flow of events and acts. Finally, the sixth layer is the outcome, which is the Sewol Ferry accident. In this layer, we have considered the sinking of the Sewol Ferry and the botched rescue attempt as two separate outcomes. In Fig. 2, each level has been depicted by a separate color code in order to highlight the impact of different layers components on each factor/box in the AcciMap. In addition, the main source of reference for each captured contributing factor has been cited in its box.

The developed AcciMap framework illustrates the contributing factors to the Sewol Ferry accident from each of the stated layers. It also depicts the interactions of different factors and involved decision-makers and key players in all these layers, which contributed to the accident. The following sub-sections provide more detail regarding the involved contributing factors in each of the stated layers of the AcciMap framework.
3.1. Government and legislation

The root causes of this accident extend beyond just blaming the captain and the crewmembers of the ship. One of the events that helped set the stage for the entire incident occurred back in 2008. Under the Lee administration, the maximum allowable age for a passenger ship went from 20 years to 30 years (Yoon, 2014).
passenger ship went from 20 years to 30 years (Yoon, 2014). This enabled Chonghaejin to purchase the 18-year-old Japanese ship, which should have been on its way out of commission.

Furthermore, the current labor market group in Korea is divided by “regular” workers, who receive traditional benefits that are enforced by Korea’s labor laws, and “irregular” workers who do not. Companies have the ability to fire irregular workers without any cause. As a result, irregular workers have less leverage with the company compared to regular workers (Koleilat, 2014). Because of the advantages of paying less and having the ability to leverage termination of employment, companies like Chonghaejin tend to hire more irregular workers than regular ones, who have more experience and knowledge in their respective fields of work.

South Korea’s not rigorous-enough ferry regulation system led to weak oversight and enforcement of government and industry regulations. According to prosecutors and government auditors, it was revealed that some of the Coast Guard officials had been negligent in their oversight of safety checks towards Chonghaejin due to the special treatment they received from this Company (Choe et al., 2014). Moreover, there was no commanding authority on-site to handle the rescuing process, which delayed action from the rescue team (연합뉴스, 2014, July 02).

3.2. Regulatory bodies and associations

In addition to the government and legislation, regulatory bodies and associations within the maritime industry did not have adequate oversight and enforcement mechanisms. Ship inspectors admitted that they only conducted a cursory inspection by eyeballing the ship’s water level in order to see whether or not it was overloaded with cargo (Choe et al., 2014). Close inspection would have revealed that on the fateful day, the Sewol had been transporting 2142 tons of cargo, which is 1155 tons over its limit (해양안전심판관 특별조사부, 2014). The configuration of the Sewol Ferry and its allowed versus actual carried load has been illustrated in Fig. 3 (There could be slight discrepancies between the stated numbers versus this figure, which was developed by the New York Times.) The fact that the Sewol Ferry was allowed to set sail that day shows serious safety gaps within the oversight of passenger ships, and inadequate regulations that allowed passenger ships such as the Sewol not to report its cargo until the voyage is over (The Associated Press, 2014).

After the redesign to the ship was made, the Korean Register of Shipping had inspected the Sewol and reduced the ship’s carrying capacity significantly to 987 tons. However, this report was only given to Chonghaejin, and neither the Coast Guard nor the Korea Shipping Association had any idea of the new capacity limits placed on the Sewol until after the incident. According to the Incheon Coast Guard, Sewol’s paperwork to the Shipping Association indicated that it was allowed to carry the total weight of 3963 tons (The Associated Press, 2014). “That’s a blind spot in the law,” states Lee Kyu-Yeul, a professor at Seoul National University’s Department of Naval Architecture and Ocean Engineering (The Associated Press, 2014). Although one regulator of South Korea had the knowledge that the ship had exceeded its capacity regularly, this information was not useful because it was not shared with other cognizant agencies with oversight responsibility for the Sewol, possibly because the law did not require it (The Associated Press, 2014).

By expanding the size of the rooms, the maximum capacity of the Ferry increased by 116 people (해양안전심판관 특별조사부, 2014). From the modification, the Sewol Ferry’s center of gravity moved upward by 51 cm and the maximum storage weight decreased from 1450 tons to 987 tons (해양안전심판관 특별조사부, 2014). However, this modification did not need any approval from the government since it did not violate Maritime Safety Code 15.2 which the company only has to get approval when the usage of the ship changes after the modification. (해양안전심판관 특별조사부, 2014).

Beyond the lack of adequate regulation and oversight, the overarching problem within the industry is the alleged corruption and collusion between government officials and businesses in South Korea. Industry analysts note that public safety officials are being lax in their duties because of the lure and prospect for lucrative positions within the private sector after their tenure in public service (Kwon, 2014). These officials were collaborating behind the scene and accommodating the very people they are supposed to be regulating. Furthermore, after these officials receive their lucrative jobs in the private enterprise, they, then, put pressure and lobby to their previous government offices, which allows these businesses to operate under even less oversight and thus, creating the perpetual cycle of deregulation and corruption, which are manifestations of the old “revolving door syndrome” and the regulatory capture phenomenon. For example, the role of Korea Shipping Association is to ensure that ships are following safety regulations. However, the Sewol Ferry disaster clearly exposed the Korea Shipping Association for woefully inadequate monitoring system to determine whether ships were within their capacity limit or, culdeacca, accurately recording their number of passengers onboard. An investigation by the Korea Broadcasting Service revealed that ten out of the twelve people on the board of directors at the Korea Shipping Association had previously held a senior position within major government bodies such as the Ministry of Oceans and Fisheries (Kwon, 2014). Further reports showed that the Korean Register of Shipping, the organization responsible for permitting the Sewol’s modifications, also had similar cases of apparent conflict of interest or commitment (Kwon, 2014). While, at first glance, the Company and its crewmembers should be held accountable for the accident, the government and its regulators were just as equally responsible for the tragedy.

Furthermore, there is an indication on the lack of a standard procedure for rescue communication by the Coast Guard. When the ship started to sink, a student onboard called 911 (119 in Korea), shouted, “Save me!” The Junnam Fire Department official referred the call over to the Mokpo Coast Guard. Thinking that the captain was the one who called, the Coast Guard official kept asking for the exact longitude and latitude of the ship. After 90 s of repetitive and complicated navigation questions, the official finally asked for the ship’s name. This event further delayed the rescue process. Marine experts indicate that asking for the ship’s name is an essential procedure one needs to do during an emergency call (JTBC, 2014).

3.3. Company management and local area planning

Chonghaejin’s serious problems were revealed through the investigation of the sinking of the Sewol. Chonghaejin’s questionable decision on grouping and scheduling two inexperienced people at a certain time played a major role in causing the sharp turn (연합뉴스, 2014, April 22). The Sewol was delayed for 2 h due to thick fog at the original port. During the voyage, Helmsman Cho who only had six months of experience controlled the steering wheel at the Maenggol Channel, where it is known to have strong underwater currents. Furthermore, the Third Mate who commanded Helmsman Cho only had experience with cargo ships. The Helmsman was originally scheduled to be commanded by the First Mate, not the Third mate. However, Chonghaejin did not change the schedule after the delay, which caused the inexperienced workers to work during a crucial period of the Maenggol Channel (연합뉴스, 2014, April 22).

Chonghaejin’s systematic violations of safety procedures were also identified; according to New York Times (Choe, 2014), “Mr. Lee
testified that his crew was simply following ‘a usual practice’ when it allowed the ship to be loaded with poorly tied-down cargo, and added that superiors ignored his complaints about overloading the vessel”. In just the 13 months preceding the accident, the ship exceeded its cargo limit an astounding 246 times out of 394 trips. Out of those 246 trips, 136 trips were reported to have exceeded 2000 tons of cargo and another 12 trips topping over 3000 tons (The Associated Press, 2014).

Furthermore, this central theme of profits over safety seems to be a recurring theme. In one of the more blatant displays of indifference for safety, Chonghaejin spent only $540 on the crew’s safety in 2013, while they proceeded to spend $10,000 for entertainment purposes and another $230,000 on Public Relations (Suh, 2014). In addition, it was revealed that the total of 19 out of 33 workers were irregular workers including the captain (Koleilat, 2014). By hiring the irregular workers who do not get benefits that regular workers do, the company paid less money to irregular working officials.

Finally, it was revealed that only 1 out of 44 lifeboats was in working condition. Korea Maritime Safety Equipment (한국해양안전관리부), the organization selected by the government, was responsible for conducting a safety test of the ship, which includes checking the rescue equipment. At least 6 auditors should have conducted a checkup for at least 5 days, but it was found that only 2 auditors spent 1.5 days (연합뉴스, 2014, July 01). This exemplifies how regulation failed to protect itself from blind spots.

3.4. Technical and operational management involved

Human error is one of the most important elements that resulted in the accident. According to Meshkati (1995), “Human ingenuity can now create technological systems whose accidents rival in their effects the greatest of natural disasters, sometimes with even higher death tolls and greater environmental damage".

The accident clearly exemplifies how the fallacy of human performance can lead to painful tragedies. To begin with, the officials in Chonghaejin did not load enough ballast water into the Sewol before the voyage (해양안전관리부, 2014). Ballast water plays a major role in balancing a ship when there are waves. Having a lack of ballast water causes the ship to capsize even with a small lateral force. In the Sewol trial that was held on June 3, 2014, the prosecutors claimed that the ship carried 2142 tons of cargoes which is 1155 tons more than the maximum permitted, and only carried 761 tons of ballast water which is 942 tons less than the minimum required to balance the maximum permitted weight (해양안전관리부, 2014). Therefore, the risky decisions of loading more than permitted cargo and less than required ballast water were two crucial contributing causes of the accident.

In addition, the cargo and the containers on the ship were not properly secured, which led to the cargo falling when the ship made a sharp turn and caused the ship to lose its balance (Park, 2014, May 15). Lashing devices, which were supposed to hold the storage tightly, were loose, and some of the crews did not even know how to use them (Park, 2014, May 15).

The Company purchased the Sewol Ferry ship, an 18-year-old retired Japanese ship. Then, it modified the ship by adding extra passenger cabins on the third, fourth, and fifth decks that altered the ship’s balance and its ability to stabilize itself (BBC News, 2014, April 30). At this point, the company had its modifications approved on the condition that the ship’s cargo capacity would not exceed 987 tons and that it would need to carry more than 2000 tons of ballast water to stay balanced. However this condition was not fulfilled during the voyage.

3.5. Accidental flow of events and acts

During the voyage, under the Third Mate Park Han-gyeol’s
command, inexperienced Helmsman Cho Joon-Ki made a 10-degree turn in one second, which caused the ship to list and tilt towards water (Jung and Lee, 2014). Considering that large passenger ships like the Sewol would take 2 min to make a 5-degree turn, the Helmsman’s decision to make the sharp turn was considered as a serious misjudgment. It caused the ship to tilt and to sink. Fig. 4 illustrates the path that the Sewol Ferry took in its last trip and its described sharp turn. This image has been captured based on the provided data from the Automatic Identification Systems (AIS) of the VTS, showing 10-s interval location, and the ship, depicting 3-s interval location.

There were instances of ineffective communication between the VTS and the ship authorities, which caused the golden time of rescuing the passengers to be wasted. When the crew was communicating with the VTS, they including the captain ignored the dispatcher’s call on evacuating the passengers (Choe, 2014). The Sewol’s communication officer concentrated on whether the Coast Guard was on its way without relaying the orders to the passengers (Bacon, 2014).

In addition, the captain and the crew did not communicate well with the passengers. As the ship was sinking, the captain repeatedly gave misleading announcements to calm people. According to the CNN (Park, 2014, April 18), the captain said, “Do not move. Just stay where you are. It’s dangerous if you move, so just stay where you are”. When everyone was moving around, confused and scared, this announcement made the passengers stay in their locations as the ship was sinking. Then the crew, against all maritime traditions and customs, left the ship without telling further instructions to the passengers who were waiting inside the vessel for an announcement. This unprecedented action led the passengers to be trapped in the tilted ship, which was later, impossible to evacuate. Captain Lee later said that “he was confused and not in his normal state of mind” due to unexpected emergency procedures (BBC News, 2014, October 7).

4. Model analysis

There are different sets of learning points from the analysis of the developed AcciMap model described in the previous section for the investigation of the Sewol Ferry accident. A very important characteristic of the AcciMap approach is placing the events and conditions that finally released the accident into the necessary context to enable the understanding that how and why the accident occurred. This characteristic avoids the unfair blame of the front-line operators, since it provides a big-picture perspective and background on where those events and conditions come from and what the sources of operators’ decisions are.

This concept in the context of analyzing the Sewol Ferry accident is equivalent to not only considering the immediate physical events and conditions or the decisions and actions made by the ship crew on the day of the accident as the contributing causes of that tragedy, but also to investigating the role and the contribution of factors in higher levels of the company or the external elements. In another word, AcciMap enables analysts to identify high-level contributing factors relating to organizational, governmental and regulatory practices as well as direct contributing causes of the outcome, by investigating all these stated factors within the scope of the illustrated levels in Fig. 2. For instance, referring to Fig. 2, one of the direct contributing factors to the sinking of Sewol was the fact that the shipping containers fell over, which created an
imbalance in the ship (Refer to the Accidental Flow of Events and Acts level). Using the AcciMap, we can trace all the other causes which led up to the shipping containers falling over.

Following the AcciMap, the lack of a central authoritative or oversight body (refer to the first level) resulted in the absence of enforcement in communication between the Korea Shipping Association and the Korean Register of Shipping (refer to the second level), who held information about the weight limit of Sewol and the amount of cargo Sewol was actually carrying, respectively. This directly contributed to Chonghaejin taking advantage of the system and regularly overloading their ship with cargo (refer to the third level). So, on the day of the accident, Sewol had 2142 tons of cargo on the ship, which was 1155 tons more than the maximum permitted (refer to the fourth level). Then, when the ship made a sharp turn (refer to the fifth level), the overloaded containers fell over (another factor in the fifth level). Consequently, this event as well as the explained decisions to increase the ship cargo load and reduce the amount of ballast water created an imbalance within the ship and the eventual sinking of the Sewol (another level in the fifth level). Through examination of the relationships between each factor as seen in this example, the AcciMap becomes a powerful tool for accident analysis and tracking the contributing factors of the accident in different analyzed levels.

Another important advantage of the AcciMap is highlighting the interactions, communication and interoperability within and between the captured levels of the framework, which each of them represents a group of decision-makers or players in the context of a studied problem. This way, it is possible to analyze and identify ineffective communication and interoperations in each level and between levels, which according to many references, they themselves are root causes of several accidents.

The current main focus of South Korea is how the country can improve its regulations, laws, policies, safety culture, and methods in preparing for the next emergency with the lessons that the Country learned from the disaster.

South Korean government needs to check upon the authorities who were in direct and indirect charge of the accident. The national government and local governments need to strengthen the regulation enforcement. Undoubtedly, the officials who were in charge of checking the cargo weights and maintenance of the ship did not fulfill their duties. In addition, the regulations need to be improved and fixed focusing more on the citizens’ safety rather than supporting businesses. Moreover, there should be more requirements regarding more effective emergency training for all maritime workers.

Patrick G. Dempsey (1987), a Lead Research Industrial Engineer at National Institute for Occupational Safety and Health, states, “Although organizations should always strive to prevent accidents, a key component of a safety program is having the resources and procedures ready to respond to an accident if an accident should occur”. From this accident, we have learned that a lack of a nation’s emergency preparedness brings about painful catastrophes. The communication between the captain and the VTS was minimal during the time of crisis. The captain repeatedly asked when the Coast Guard will arrive and did not listen to the VTS’s instruction. Some of the VTS officials’ messages were not delivered properly to the Sewol officials due to misunderstandings, which led the Sewol officials to miss out on its golden time to rescue people. Because the VTS had to rely on information that the captain gave to figure out the situations, the VTS could not give clear instructions and advice.

To make a clear judgment during emergency events, there needs to be enough data to understand and have an awareness of the situation. The first step in achieving situation awareness is to perceive the status, attributes, and dynamics of relevant elements in the environment (Endsley, 1987).

Whenever the VTS asked about the conditions and situations, the captain had to guess the measurements and situations. By observing his answers, it is definite that the captain was uncertain about the situation. There are three categories needed in the emergency assessment: situation measurement, subjective measurement, and performance measurement. Clearly, the captain of the 18-year-old ship lacked all three categories of these systems to allow him to make a clear judgment, which ultimately led the captain into thinking that it was too late for the passengers to abandon the ship. Even old ships like the Sewol need more situation awareness systems for the decision makers in the ship and the officials who help from outside such as the VTS. Moreover, in order to analyze tragedies for future studies on improving regulations and safety culture, ships need Video Disk Recorders (VDR) and other situation recording devices, which the Sewol did not have any of them (혈액안전관리원 특별조사부, 2014).

Finally, although it is impossible to create a 100-percent-error-free system, incorporating different defensive layers, known as barriers, as well as measurable attributes to monitor safety and reliability of high-risk operations is useful in developing proactive risk management systems in order to prevent future incidents and accidents. In this regard, the analysis of previous incidents using accident analysis methodologies is beneficial in identifying proper described barriers and attributes.

5. Conclusion

This paper described the application of the AcciMap methodology to capture and analyze the contributing causes of the Sewol Ferry accident, as one of the worst maritime accidents in the history of South Korea. This methodology enables analysts to identify high-level contributing factors relating to organizational, governmental and regulatory practices as well as direct contributing causes of an outcome, by investigating all these stated factors within the scope of the illustrated levels in Fig. 2.

The AcciMap approach is a useful framework to model a broader socio-technical context, in which an accident unfolds, in a coherent diagram and illustrate different contributing factors of that accident and their interactions. This way, unfairly blaming front-line operators will be avoided and in a broader perspective, the sources of those operators’ decisions and actions will be analyzed. In the case of the Sewol Ferry accident, a lot of the blame has placed on the shoulder of the Sewol’s captain and its crewmembers. However, according to this study, the disaster is the result of a series of lapses and disregards for safety across different levels of government and regulatory bodies, Chonghaejin Company, and the Sewol’s crewmembers. The primary layers of the AcciMap framework, which include the political environment and non-proactive governmental body; inadequate regulations and their lax oversight and enforcement; poor safety culture; inconsideration of human factors issues; and lack of and/or outdated standard operating and emergency procedures were not only limited to the maritime industry in South Korea, and the Sewol Ferry accident, but they could also subject any safety-sensitive industry anywhere in the world.

Professor Rasmussen’s AcciMap methodology, which is one of his many legacies, enabled us to systematically analyze the contributing causes of the Sewol Ferry accident. We hope that this study and its lessons learned contributes to preventing similar accidents like the Sewol, which is considered as a national disaster in South Korea, in the future.

Finally, the following perceptive statement by Professor Jens Rasmussen in his seminal paper, which introduced the AcciMap framework for the first time (Rasmussen, 1997, p.193), succinctly summarizes this study and its conclusion:
“From a control point of view, the interaction among the decision-makers potentially involved in accident causation has some very special features. All these decision makers are busy managing their particular work domains and their attention will be focused on the control of the means and ends of their normal productive tasks while they strive to meet their production targets, often under considerable stress to optimise process criteria such as time spent and cost-effectiveness. This must be done while respecting the constraint defined for their local context, including the boundaries defining safe overall operation. A critical issue is that the boundaries relevant to a particular decision maker depend on the activities of several other decision makers found within the total system and that accidents are created by the interaction of potential side effects of the performance of several decision makers during their normal work” (emphasis in original).

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References