

## Needs for Changing Accident Investigation from Blaming to Systems Approach

Dohyung Kee

Department of Industrial and Management Engineering, Keimyung University, Daegu, 42601

### Corresponding Author

Dohyung Kee  
Department of Industrial and  
Management Engineering, Keimyung  
University, Daegu, 42601  
Mobile : +82-10-5656-1260  
Email : dhkee@kmu.ac.kr

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**Objective:** The purposes of this study are to survey needs for changing accident investigation from blaming to systems approach and to briefly summarize systems-based accident analysis techniques.

**Background:** In modern complex socio-technical systems, accidents are caused by a variety of contributing factors including human, technical, organizational, social factors, not by just a single violation or error of a specific actor, but accidents investigation used to be focused on the incorrect action of individuals. A new approach investigating causes of accidents as a symptom of a deficient system is required.

**Method:** This study was mainly based on survey of literatures related to accidents, accidents investigation, which included academic journals, newspapers, etc.

**Results:** This study showed that accidents investigation of Korea focusing on blaming is problematic. This was confirmed by two concepts of migration and hindsight bias frequently found in accident causation studies, and an attribute of accidents having varying causes. This was illustrated with an example of Sewol ferry capsizing accident. Representative systems-based accident analysis models including Swiss cheese model, AcciMap, HFACS, FRAM and STAMP were briefly introduced, which can be used in systematic accidents investigations. Finally, this study proposed a procedure for establishing preventive measures of accidents, which was composed of two steps: public inquiry and devising preventive measures.

**Conclusion:** A new approach considering how safety-critical components such as technical and social elements, and their interactions lead to accidents is needed for preventing reoccurrence of similar accidents in complex socio-technical systems.

**Application:** The results would be used as a reference or guideline when the safety relevant governmental organizations investigate accidents.

**Keywords:** Accidents, Accident investigation, Systems approach, Blaming

### 1. Introduction

In modern complex socio-technical systems like nuclear power plants, ships, high speed trains, airplanes, etc., accidents are known to be caused by a variety of contributing factors including human, technical, organizational, social factors, not by just a single unusual decision or action of a specific actor (Heinrich et al., 1980; Reason, 1995; Shappell and Wiegmann, 2000; Turner, 1978; Vicente and Christoffersen, 2006; Waterson, 2009). Accidents are just the end result of a number of causes, only the last of which are the unsafe acts of actors (Bird, 1974; Heinrich et al., 1980; Reason,

1990; Shappell and Wiegmann, 2000). Accordingly, an explanation of the accidents in terms of events, acts, and errors is not very useful for designing improved systems (Rasmussen, 1997).

Accidents investigation should not focus on human errors and violations that triggered the accident, but on the mechanisms generating the errors and violations in the actual, dynamic socio-technical context (Branford, 2011; Rasmussen, 1997; Rasmussen and Svedung, 2000; Vicente and Christoffersen, 2006). On the contrary to this requirement, in Korea, accidents investigation generally focuses on human errors or violations releasing the accidents, for assigning blame for the accidents. In other words, the main concern of accidents investigation is to find out persons in charge of accidents and to assign criminal punishment to them, rather than to survey objective causes of accidents. This is backed by the fact that in the Sewol disaster, the prosecution criminally charged over 300 personnel concerned, and much blame for the disaster has fallen on the Sewol's crew members including captain, Chonghaejin Marine Company's owner, and high-rank officials including president. As a result, it is general that many personnel directly or indirectly related to the accidents are legally placed under arrest on charge of not observing relevant regulations and laws (Chosun-Ilbo(d), 2014), and that many high-rank officials including ministers of relevant governmental departments and prime minister voluntarily resign their positions or are dismissed (Chosun-Ilbo(a), 2014). In the Sewol's accident, general public of Korea often required that even president step down with assuming responsibility of the accident (Chosun-Ilbo(b), 2014).

Vicente and Christoffersen (2006) suggested that when the goal of accidents investigation is to assign blame, the results may provide too superficial an explanation of why the accidents occurred to prevent similar losses. In addition, in Korea, the investigation has been conducted by relevant governmental departments or agencies, which mainly dealt with their management after accidents such as compensation for the victims, rather than systematic analysis of their causes. These may be one of the main reasons that there have been no significant lessons learnt from past accidents, which resulted in repetition of similar man-made big tragedies with over 100 deaths for the last two decades such as Seohae ferry sink (1993, 292 deaths), Daegu subway gas explosion (2003, 101 deaths), Samping Department Store collapse (1995, 502 deaths), Daegu subway train fire (2003, 192 deaths) and Sewol ferry capsizing (2014, 294 deaths) (Chosun-Ilbo(c), 2014).

The purposes of this study are to survey needs for changing accident investigation from blaming to systems approach and to briefly introduce systems approach techniques for accidents investigation.

## 2. Method

This study was conducted mainly based on survey of literatures related to accidents, accidents investigation. Data for the Sewol ferry capsizing accident, which was used as an example in this study, were collected from the following two sources: 1) Interim post-accident report by the Board of Audit and Inspection of Korea (BAI) (BAI, 2014); 2) articles including columns and editorials in major domestic newspapers, such as Chosun-ilbo, Donga-ilbo, Monthly Chosun of Korea from April 2014 to October 2014.

## 3. Results

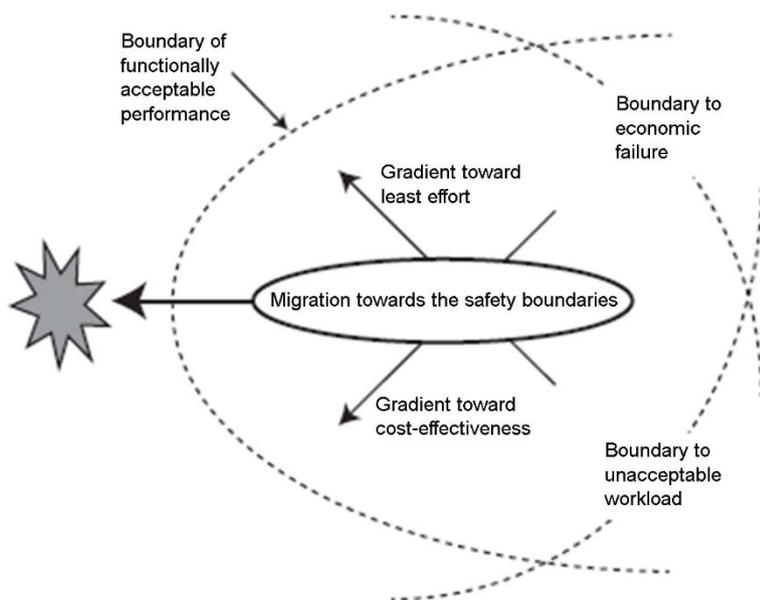
### 3.1 Needs for changing accident investigation

#### 3.1.1 Migration

Rasmussen (1997) proposed a process of migration to explain how accidents can occur in the complex socio-technical systems. Human behaviour in any work system is shaped by objectives and constraints which must be respected by the actors for work performance to be successful. Aiming at such productive targets, however, many degrees of freedom are left open which will have

to be closed by the individual actor by an adaptive search guided by process criteria such as work load, cost effectiveness, risk of failure, joy of exploration, etc. The work space within which the human actors can navigate freely during this search is bounded by administrative, functional, and safety related constraints. Such local, situation-induced variations within the work space call to mind the 'Brownian movements' of the molecules of a gas. During the adaptive search the actors have ample opportunity to identify 'an effort gradient' and management will normally supply an effective 'cost gradient'. The result will very likely be a systematic migration toward the boundary of functionally acceptable performance and, if crossing the boundary is irreversible, an error or an accident may occur (Rasmussen, 1997).

Within a competitive environment, people throughout the system are under pressure to work in a cost-effective manner. This cost gradient pushes workers, and the system as a whole, toward efficiency and away from the boundary to economic failure. At the same time, an effort gradient directs them away from unacceptable workloads and toward easier ways to work. As a result of these pressures, work practices go through a migration process, as workers throughout the system seek a balance between effort and cost-effectiveness in their work (Vicente and Christoffersen, 2006). The result is movement toward the boundary of functionally acceptable performance and, when this boundary is crossed, an accident or an error can occur (Rasmussen, 1997) (Figure 1).



**Figure 1.** Schematic diagram of migration

The problem is that in a system having functionally redundant protective defenses, a local violation of one of the defenses has no immediate, visible effect and then may not be observed in action. In other words, individuals in such system cannot judge where the safety boundaries relevant to their activities actually lie, because the location of these boundaries depends on the decisions and activities of other people, at different times, in different parts of the system. The effectiveness of the system defenses protecting one individual is dependent on the extent to which the defenses have been violated by others in the system and the extent to which redundant and overlapping defenses are intact, neither of which are visible to workers (Rasmussen, 1997). The actual boundaries of safe performance only become visible after they have been crossed and an accident occurs. At this point, the relationship between the independent activities of the different individuals becomes clear, and degradation in safety that may have

been occurring over a number of years is revealed (Branford, 2011; Rasmussen, 1997; Svedung and Rasmussen, 2002).

Rasmussen (1997) suggested that when accidents occur, the stage for an accidental course of events has usually been developing over time, through the efforts of workers throughout the system to work efficiently and cost-effectively. Correspondingly, it is often concluded by accident investigations that the particular accident was actually waiting for its release. In this situation, normal variation in somebody's behaviour then serves to release accidents. Frequently, that individual will not understand what has happened because this behavior was not particularly different from past behaviors that had no negative effects (Vicente and Christoffersen, 2006). This decision or action is often viewed as a primary cause of the accident even though it is likely that, had the particular root cause been avoided by some additional safety measure, the accident would very likely be released by another cause at another point in time. For this reason, Rasmussen and Svedung (2000) suggest that explanations of system accidents should not focus on the actions or errors that triggered the event, but on the broader socio-technical context in which these events unfolded. A new approach to representation of system behaviour is necessary, not focused on human errors and violations, but on the mechanisms generating behaviour in the actual, dynamic work context (Rasmussen, 1997).

### 3.1.2 Hindsight bias

Hindsight bias, also known as the knew-it-all-along effect or creeping determinism, is defined by the inclination, after an event has occurred, to see the event as having been predictable, despite there having been little or no objective basis for predicting it. It is a multifaceted phenomenon that can affect different stages of designs, processes, contexts, and situations. A basic example of the hindsight bias is when, after viewing the outcome of a potentially unforeseeable event, a person believes he or she knew it all along. Such examples are present in the writings of historians describing outcomes of battles, physicians recalling clinical trials, and in judicial systems trying to attribute responsibility and predictability of accidents (Wikipedia homepage, 2016).

The tendency to attribute accidents to simple causes such as isolated front-actor's failures is derived in part from a particular form of bias that clouds post-accident reviews of human performance. It is well documented that knowledge of outcome biases our later judgments about the processes that led up to that outcome (Figure 2). The way we look back is shaped by the outcome. That outcome knowledge, however, was not available to the participants before the fact. In looking back we tend to oversimplify the situation that individuals in a system actually faced. This blocks our ability to see the more complicated, richer story behind the label human error (Cook et al., 1998). In viewpoint of the hindsight bias, an accident is simply caused by a single unusual decision or action of a front-actor. Therefore, a new approach or viewpoint is needed to see the big picture of accidents.

### 3.1.3 Attribute of accidents having multiple causes

It is explained with an example of the Sewol ferry capsizing accident that accidents are attributed to a variety of contributing factors, not by just a single unusual human error or violation which finally triggers them. The Sewol ferry accident is briefly stated in the following.

On 15<sup>th</sup> April 2014, the Korean ferry of the Sewol, carrying 476 people which included 325 high school students, left Incheon port for Jeju island. The ferry capsized in the sea 3.3km north Byungpoong island (narrow waterway called the Maenggol Strait) with treacherous currents about 13 hours after its departure. The accident claimed the lives of 295 passengers, the vast majority of whom were students of a high school on a four-day excursion trip to the island. Nine passengers on board still remain missing as of November 2014, and search activity for the missing finally ended at 11 November 2014, 209 days after the accident (Chosun-Ilbo(f), 2014). The ship remains where it sank.

The direct and indirect causes of the Sewol accident can be listed as follows:

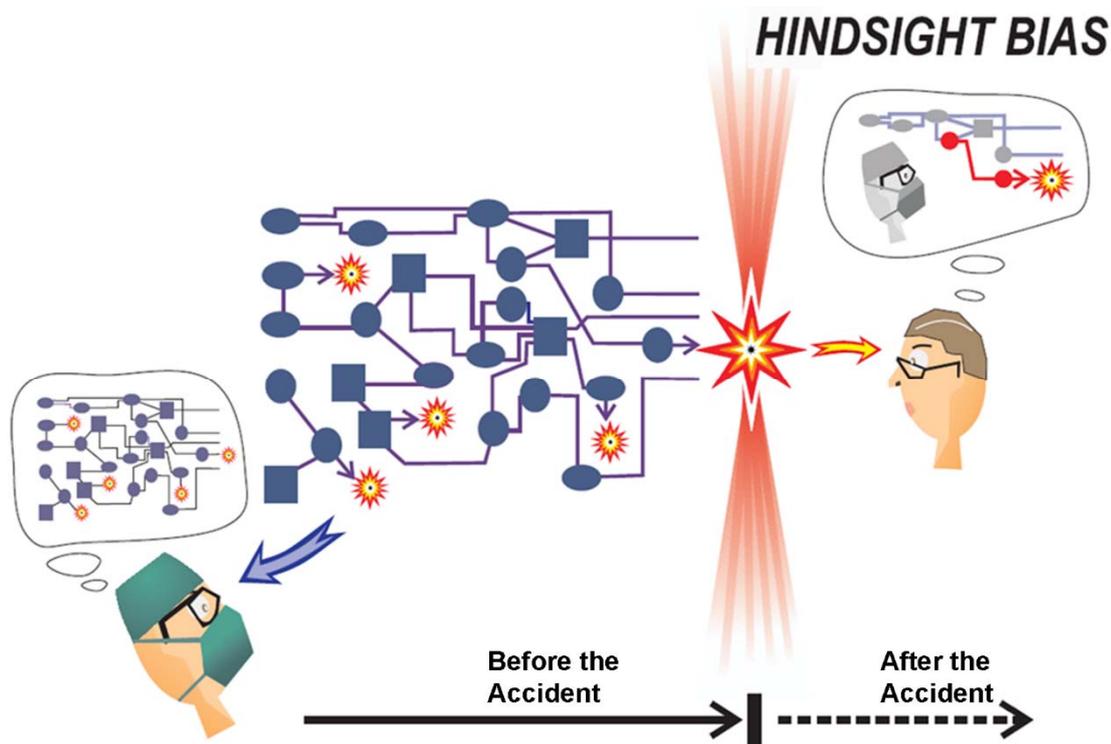


Figure 2. Hindsight bias

- Crew members' violations and decision errors such as poor restoring force, shift of improperly secured cargos and sudden turn of ship
- Poor rescue operation attributed to poor initial measures by crew members, confusing exit routes, problems with on-board life rafts, delayed report to authorities and arrival of rescuers, and poor initial rescue operation
- Negligence and complacency of the marine inspector
- Crew members' lack of professionalism and negligence
- Chonghaejin Marine Company's policies prioritizing short-term profit, employing low paid contract workers and neglecting maintenance for the ferry
- Lack of human resource training
- Relevant organizations' wrong authorization on the ferry's expansion and lack of independence
- Ministry of Oceans and Fisheries (MOF) officials' negligence, loophole of ship relevant law, and Korea's social environment
- Government's lack of relevant manuals for marine accidents and coordination

The above shows that there were varying causes from front-actors to government in the Sewol accident. This means that accidents should be holistically investigated to include all the contributing factors.

### 3.2 Accidents investigations of Korea

The Sewol ferry accident was also used as an example to show the real state of Korea's accidents investigations. In the initial stage of the accident, the police and prosecution, and the Board of Audit and Inspection of Korea (BAI) mostly investigated the accident. Based on the investigation, the prosecution criminally charged 399 personnel concerned, and imprisoned 154 of them as of October

2014. Some of the trials for the imprisoned are completed and some are underway as of February 2016 (Chosun-Ilbo(d), 2014). The BAI performed administrative inspections for the MOF, the Korean Coast Guard (KCG), the Ministry of Security and Public Administration (MSPA), etc. for 23 days from May 14, 2104 to June 20, 2014, and presented an interim investigative report for the inspections on July 8, 2014 (BAI, 2014). The parliamentary investigation had been done under the agreement of the major political parties from June 2, 2014 to August 30, 2104. The investigation was finished without results such as expiscating objective causes of the accident, due to the political interest conflict between the parties. The Sewol's special law was passed by the National Assembly on November 7, 2014. On the basis of the law, a select committee consisting of 17 members was organized and began to investigate the accident over six months later than the statutory schedule of January 1, 2015 (Chosun-Ilbo(e), 2014). More than six months have passed since the committee started the investigation, the committee has not produced any objective or meaningful result. Judging the number of imprisonment, investigation result and process, the investigations by the prosecution, National Assembly and the Sewol's select committee mainly focused on to find out who to blame, rather than to seek objective causes of the disaster.

### 3.3 Systems approaches

Several systems approaches have been used for analysing accidents occurring in the complex socio-technical systems, which are capable to accommodate varying contributing factors both from within different parts of the systems and interactions between them, and from even external influences such as political, financial, and technological circumstances (Branford, 2011). Following the prominence of individual focused approaches to accident causation in the late 1970s, the systems approaches to human error began to gain credence during the 1980s due to a series of catastrophes in which managerial failures were identified as key contributing factors (Salmon et al., 2010). Up to now, varying systems techniques have emerged including Swiss cheese model (Reason, 1990), AcciMap (Rasmussen, 1997, Svedung and Rasmussen, 2002), HFACS (Shappell and Wiegmann, 2000), FRAM (Hollnagel, 2004), STAMP (Leveson, 2004), etc.

- Swiss cheese model: developed by Reason, which is based on a layer by layer description of complex systems (e.g. decision makers, line management, productive activities and defences), and focuses on the interaction between system-wide inadequate (referred to as latent) conditions and errors and their contribution to organizational accidents. The model was applied to analysis of accident causation of aerospace industry (Shappell and Wiegmann, 2000).
- AcciMap: developed by Rasmussen, which is an accident analysis method that graphically represents the decision makers and decisions involved in producing the system in which an accident was permitted to occur. Here, the complex socio-technical systems involved in risk management generally consist of five levels including government, regulators and associations, company, management, and staff and work (Branford, 2011). The model was widely used to investigate accidents occurred in patient safety (Waterson, 2009), aerospace industry (Branford, 2011; Johnson and Muniz de Almedia, 2008), led outdoor activity (Salmon et al., 2010), public health sector (Vicente and Christofferson, 2006; Woo and Vicente, 2003), road traffic (Svedung and Rasmussen, 2002), shooting case (Jenkins et al., 2010), etc.
- HFACS: developed by Shappell and Wiegmann, which is based on sound human error theory (Murray, 2013). The model used Reason's (1990) four levels of failure leading to an accident, which include organizational influences, unsafe supervision, pre-conditions for unsafe acts and unsafe acts, and was applied to military, civil aviation, mining, ship industry (Murray, 2013).
- FRAM: developed by Hollnagel to act as both an accident analysis and risk assessment tool. The model graphically describes systems as a network of interrelated sub-systems and functions which, although designed otherwise, will exhibit varying degrees of performance variation (Hollnagel and Goteman, 2004). There are number of examples for both methods of application, e.g. aircraft collisions (Herrera and Woltjer, 2010) and rail network control (Belmonte et al., 2011).
- STAMP: introduced by Leveson and describes systems as a 'hierarchy of control based on adaptive feedback mechanisms and provides an understanding of how a lack of system safety control, at both the design and operational stages, produces accidents (Leveson, 2004). The model was used in retrospective and prospective analyses within various domains, e.g. aerospace (Johnson

and Holloway, 2003) and led outdoor activities (Salmon et al., 2012).

Reason's cheese model and AcciMap are the generic approaches without taxonomies of failures, which can produce different analysis results according to analyzers. HFACS and STAMP provide taxonomies of failure modes based on Reason's explanation of active and latent failures (Reason, 1990). AcciMap and STAMP are similar to that they view systems as hierarchical levels of controls and constraints, but they are different from that while AcciMap has a hierarchical structure with various system levels (e.g. government, regulators, company, company management, staff, and work), STAMP has two separate structures for system development and system operations. Unlike AcciMap and STAMP having hierarchical structures with varying system levels, FRAM describes systems as a network of interrelated sub-systems and functions, which are directly and indirectly connected (Hollnagel and Goteman, 2004).

### 3.4 Establishing preventative measures of similar accidents

For avoiding similar big accidents, a public inquiry should be firstly conducted without limitation on its duration by an independent committee consisting of governmental officials as well as safety experts, journalists, academics, etc., not by just governmental officials, prosecution, political parties as done in Korea. The public inquiry contains varying types of inquiries such as examination of relevant documents, hearing, interviews with personnel concerned, etc. This public inquiry may act as a vehicle for better understanding accidents, and serve as a stimulus to safety cultural change (Elliott and Smith, 2006). The public inquiry should be impartial and objective so that new guidelines or regulations from the inquiry can be reflected into practice. The results from the inquiry should be institutionalized into countermeasures such as new norms, regulations and infrastructure (Elliott and Macpherson, 2010). Of the countermeasures, regulation is regarded as the most effective to such an extent to which safety measures cannot be secured without legislation (Elliott and Smith, 2006).

Next, preventive measures are established based on the inquiry's results. It should be noted that just adding more defenses in depth, such as new policies and procedures or calls to increase the vigilance of the actors, is unlikely to work as long-term solutions. It is because the defenses are likely to degenerate systematically through time under two migration gradients of cost- and effort-effectiveness (Cook et al., 1998; Rasmussen, 1997; Vicente and Christoffersen, 2006). These migrations of work practices can occur at multiple levels of a complex socio-technical system, but before accidents, the varying actors of the system, such as front-line operators, safety officers, company managers, regulators, governmental officials, politicians, etc., do not recognize how their actions interact with those made by other actors at different levels of the system (Rasmussen, 1997; Vicente and Christoffersen, 2006). Only after accidents, the actor can see the results of their interactions. Therefore, the countermeasures should be based on the system's prospective considering the vertical integration of all actors in the system via feedback across levels so that they can see how their actions affect the whole system's safety (Vicente and Christoffersen, 2006). Since failures at higher systemic levels to perform safety check regularly, such as company, local authority, regulatory bodies and government, can play a critical role in accidents and incidents in the safety-critical domains, the countermeasures should place more emphasis on changes for the higher levels, rather than those for the front-line operators (Hollnagel, 2004; Rasmussen, 1997; Reason, 1990; Salmon et al., 2010).

## 4. Discussion and Conclusions

Accident investigation is the most widely used method for clarifying the basic, contributing and immediate causes of accidents and for identifying appropriate measures to prevent occurrence of similar events in the future (Roed-Larson et al., 2004). This study showed that accidents investigation focused on the incorrect actions of individuals needs to be changed. In addition, this viewpoint has known to have some problems. First, this punitive approach is likely to achieve rigid compliance with written regulations, but it is less likely to achieve the safety cultural change inevitably needed not to repeat similar accidents (Elliott, 2009; Elliott and Smith, 2006). Second, it provides only a partial view of the hazards and of the factors that contribute to accidents (Cook

et al., 1998; Vicente and Christoffersen 2006). The accidents cannot be attributed to an error or an one-time threat to safety, but to a combination of systematically-induced migration in work practices and an odd event that wound up revealing the degradation in safety that had been occurring all the while (Vicente and Christoffersen, 2006). Rasmussen (1997) asserted that if just the error or threat to safety had been avoided by some additional safety defenses, the accident would very likely happen by another cause sometimes. Third, when adopting this approach, finding the people blamed tends to end the investigation (Cook et al., 1998). Fourth, after accident, looking back at the accident often brings about tendency to oversimplify the situation of the accident, i.e., to attribute the accident to simple causes such as isolated human errors. The tendency can be explained in part by a particular form of hindsight bias. In other words, knowledge of the accident biases our later judgments about the processes that led up to the accident (Cook et al., 1998). Therefore, a new approach to the accidents investigation should be adopted in Korea, based on the mechanisms generating those misbehaviors in the complex socio-technical systems, not on finding out who to blame. It is expected that the Sewol's accident would be a turning point of taking up a new systematic approach for accident investigation.

Secondly, this study summarized the systems approaches including Swiss cheese model, AcciMap, HFACS, FRAM and STAMP. The techniques are now the dominant approach to error and error management in most safety-critical domains (Salmon et al., 2010). These systems-based accident causation/analysis models are used to reconstruct accidents so that both the human and wider system contributions to accidents or incidents can be identified.

In addition, this study suggested a procedure establishing preventative measures of accidents, which is summarized in the following (see 3.4). First of all, accidents should be systematically investigated through the objective public inquiry. It should be noted that during the initial stage of accidents including the inquiry, the media should be patient to wait for its investigation results, instead of competitively reporting sensational breaking news. The competitive breaking news can bring about makeshift measures rather than permanent ones (Monthly Chosun, 2016). Reflecting this, five major media organizations of Korea declared the disaster reporting guidelines consisting of 44 provisions on September 16, 2014. The guidelines include accurate reporting, prioritizing saving lives and collecting the dead, minimization of loss, providing information on countermeasures, prohibition of unethical news-gathering, refraining from unreasonable competition in coverage, verification for news source, protection of victims, etc (Donga-Ilbo, 2016). Next, the findings from accidents investigation are then used to inform the development of measures to ensure that similar accidents do not occur again (Salmon et al., 2010).

## References

- Belmonte, F., Schoen, W., Heurley, L. and Capel, R., Interdisciplinary safety analysis of complex socio-technological systems based on the functional resonance accident model: An application to railway traffic supervision, *Reliability Engineering & System Safety*, 96(2), 237-249, 2011.
- BAI (Board of Audit and inspection of Korea), *Status on Audit progress*, 2014.
- Bird, F., *Management guide to loss control*, Institute Press, Atlanta, GA, 1974.
- Branford, K., Seeing the big picture of mishaps: Applying the AcciMap approach to analyze system accidents, *Aviation Psychology and Applied Human Factors*, 1(1), 31-37, 2011.
- Chosun-Ilbo(a), PM Chung resigned, [http://news.chosun.com/site/data/html\\_dir/2014/04/28/2014042801155.html](http://news.chosun.com/site/data/html_dir/2014/04/28/2014042801155.html) (retrieved February 15, 2016).
- Chosun-Ilbo(b), Critics saying that president should step down, [http://news.chosun.com/site/data/html\\_dir/2014/04/29/](http://news.chosun.com/site/data/html_dir/2014/04/29/)

2014042900055.html (retrieved February 15, 2016).

Chosun-Ilbo(c), Do not forget, [http://news.chosun.com/site/data/html\\_dir/2014/05/09/2014050903758.html](http://news.chosun.com/site/data/html_dir/2014/05/09/2014050903758.html) (retrieved February 15, 2016).

Chosun-Ilbo(d), National Intelligence Service intervened illegal Sewol expansion, [http://news.chosun.com/site/data/html\\_dir/2014/07/25/2014072503031.html](http://news.chosun.com/site/data/html_dir/2014/07/25/2014072503031.html) (retrieved February 15, 2016).

Chosun-Ilbo(e), Parliamentary passage of Sewol special law, [http://news.chosun.com/site/data/html\\_dir/2014/11/08/2014110800252.html](http://news.chosun.com/site/data/html_dir/2014/11/08/2014110800252.html) (retrieved February 15, 2016).

Chosun-Ilbo(f), Searching for missing of Sewol finished, [http://news.chosun.com/site/data/html\\_dir/2014/11/11/2014111101158.html](http://news.chosun.com/site/data/html_dir/2014/11/11/2014111101158.html) (retrieved February 15, 2016).

Cook, R.I., Woods, D.D. and Miller, C., *A tale of two stories: Contrasting views of patient safety*, National Health Care Safety Council of National Patient Safety Foundation at the AMA, 1998.

Donga-Ilbo, When reporting disaster, priority should be given to accuracy rather than speed, (retrieved February 15, 2016).

Elliott, D., The failure of organizational learning from crisis - A matter of life and death?, *Journal of Contingencies and Crisis Management*, 17(3), 157-168, 2009.

Elliott, D. and Macpherson, A., Policy and practice: Recursive learning from crisis, *Group & Organization Management*, 35(5) 572-605, 2010.

Elliott, D. and Smith, D., Cultural readjustment after crisis: Regulation and learning from crisis within the UK soccer industry, *Journal of Management Studies*, 43(2), 289-317, 2006.

Hollnagel, E., *Barriers and accident prevention*, Akdershot: Ashgate Publishing Limited, 2004.

Hollnagel, E. and Goteman, Ö., The functional resonance accident model, In. *Cognitive System Engineering in Process Control*, 2004.

Heinrich, H.W., Petersen, D. and Roos, N., *Industrial accident prevention: A safety management approach* (5th ed.), New York, McGraw-Hill, 1980.

Herrera, I.A. and Woltjer, R., Comparing a multi-linear (STEP) and systemic (FRAM) method for accident analysis, *Reliability Engineering & System Safety*, 95(12), 1269-1275, 2010.

Jenkins, D.P., Salmon, P.M., Stanton, N.A. and Walker, G.H., A systemic approach to accident analysis: A case study of the Stockwell shooting, *Ergonomics*, 53(1), 1-17, 2010.

Johnson, C.W. and Muniz de Almeida, I., Extending the borders of accident investigation: applying novel analysis techniques to the loss of the Brazilian space launch vehicle VLS-1 V03, *Safety Science*, 46(1), 38-53, 2008.

Johnson, C.W. and Holloway, C.M., The ESA/NASA SOHO mission interruption: Using the STAMP accident analysis technique for

a software related 'mishap', *Software: Practice and Experience* 33(12), 1177-1198, 2003.

Leveson, N., A new accident model for engineering safer systems, *Safety Science*, 42(4), 237-270, 2004.

Monthly Chosun, 10<sup>th</sup> anniversary of Daegu Subway fire disaster, <http://monthly.chosun.com/client/news/viw.asp?ctcd=C&nNewsNumb=201302100027> (retrieved February 15, 2016).

Murray, S., *A proposed technique to identify human and organisational factors in accident investigations in the marine industry*, unpublished Master Thesis, School of the Built Environment, Heriot-Watt University, 2013.

Rasmussen, J., Risk management in a dynamic society: A modelling problem, *Safety Science*, 27, 183-213, 1997.

Rasmussen, J. and Svedung, I., *Proactive risk management in a dynamic society Karlstad, Sweden*, Swedish Rescue Services Agency, 2000.

Reason, J., *Human error*, New York, Cambridge University Press, 1990.

Reason, J., A systems approach to organizational error, *Ergonomics*, 38, 1708-1721, 1995.

Roed-Larson, S., Valvisto, T., Harms-Ringdahl, L. and Kirchsteiger, C., Accident investigation practices in Europe—main responses from a recent study of accidents in industry and transport, *Journal of Hazardous Materials*, 111, 7-12, 2004.

Salmon, P., Williamson, A., Lenné, M., Mitsopoulos-Rubens, E. and Rudin-Brown, CM., Systems-based accident analysis in the led outdoor activity domain: application and evaluation of a risk management framework, *Ergonomics*, 53(8), 927-939, 2010.

Salmon, P.M., Cornelissen, M. and Trotter, M.J., Systems-based accident analysis methods: A comparison of Accimap, HFACS, and STAMP, *Safety Science*, 50, 1158-1170, 2012.

Shappell, S.A. and Wiegmann, D.A., *The human factors analysis and classification system-HFACS*, U.S. Department of Transportation, Federal Aviation Administration, 2000.

Svedung, J. and Rasmussen, J., Graphic representation of accident scenarios: mapping system structure and the causation of accidents, *Safety Science*, 40, 397-417, 2002.

Turner, B.A., *Man-made disasters*, Wykeham Publications, London, 1978.

Vicente, K.J. and Christoffersen, K., The Walkerton E. coli outbreak: A test of Rasmussen's framework for risk management in a dynamic society, *Theoretical Issues in Ergonomics Science*, 7(2), 93-112, 2006.

Waterson, P., A systems ergonomics analysis of the Maidstone and Tunbridge Wells infection outbreaks, *Applied Ergonomics*, 52(10), 1196-1205, 2009.

Wikipedia homepage, hindsight bias, [https://en.wikipedia.org/wiki/Hindsight\\_bias](https://en.wikipedia.org/wiki/Hindsight_bias) (retrieved February 16, 2016).

Woo, D.M. and Vicente, K.J., Sociotechnical systems, risk management, and public health: Comparing the North Battleford and

Walterton outbreaks, *Reliability Engineering and System Safety*, 80, 253-269, 2003.

## Author listings

**Dohyung Kee:** dhkee@kmu.ac.kr

**Highest degree:** Ph.D., Department of Industrial Engineering, POSTECH

**Position title:** Professor, Department of Industrial and Management Engineering, Keimyung University

**Areas of interest:** Systems ergonomics, Population stereotype, Product design, Posture classification scheme, Industrial safety, Musculoskeletal disorders