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An application of AcciMap to identify and analyse the causes of the Eastern Star and Sewol casualties

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AN APPLICATION OF ACCIMAP TO IDENTIFY AND ANALYSE THE CAUSES OF THE EASTERN STAR AND SEWOL CASUALTIES

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **An application of AcciMap to identify and analyse the causes of the Eastern Star and Sewol Casualties**

Degree: **MSc**

Thanks to the technological advances and strengthened system of global maritime governance especially by IMO, occurrence of accidents in the maritime domain has not increased with the continuing seaborne trade. However, potential risks on the ships that were not under IMO regime should be concerned more seriously especially after the two Asian casualties of Eastern Star and Sewol occurred in recent years.

The purpose of this research is to apply a recognized accident investigation method to identify and analyse the causes of these tragedies and give some recommendations based on the outcome of the research. After comparing with several popular investigation methods, AcciMap was chosen as a harmonized approach to make the research due to its advantages in organizational factors analysis and corresponding recommendations exportation. The research contributes progresses in the application of AcciMap in two significant events and provided some measures to prevent repetitions of such disasters. However, further research is needed to further develop the method due to the constraints in the approach itself but also due to weakness in information collection and research limitations as well.

KEYWORDS: Organizational Factors, ActorMap, AcciMap, Eastern Star, Sewol, Factual information, Identified Failures.

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LIST OF ABBREVIATIONS

IMO	International Maritime Organization
GDP	Gross domestic product
USD	United States Dollar
UNCTAD	United Nations Conference on Trade and Development
SOLAS	International Convention for the Safety of Life at Sea
GPS	Global Positioning System
AIS	Automatic identification system
ECS	Electronic Chart System
VHF	Very High Frequency
PA	Public Announcement
ETA	Estimated Time of Arrival
SAR	Search and Rescue
MV	Motor Vessel
KCG	Korea Coast Guard
UNCLOS	United Nations Convention on the Law of the Sea
MARPOL	International Convention for the Prevention of Pollution from Ships
SOS	Save Our Ship
MSC	Marine Safety Committee of International Maritime Organization
FTA	Fault Tree Analysis
HFACS	Human Factors Analysis and Classification System
STAMP	System-Theoretic Accident Model and Processes
SNA	Social Network Analysis
CPA	Critical Path Analysis

EAST	Event Analysis of Systemic Teamwork
WMU	World Maritime University
MARISA	Maritime Risk and System Safety
MSA	Maritime Safety Administration
SASAC	State-owned Assets Supervision and Administration Commission
MOT	Ministry of Transport
MIIT	Ministry of Industry, Information and Technology
CMA	China Meteorological Administration
CCS	China Classification Society
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

1 Introduction

2.1 Background

It is well accepted that 90% of the global trade is carried out by the shipping industry (George, 2013). With the continued increase in population, the existing economy is keeping a growing trend and resulting in a rise in the demand for seaborne trade. This trend is primarily driven by growth and expansion in developing countries, leading to changes in trading patterns. (Figure 1)

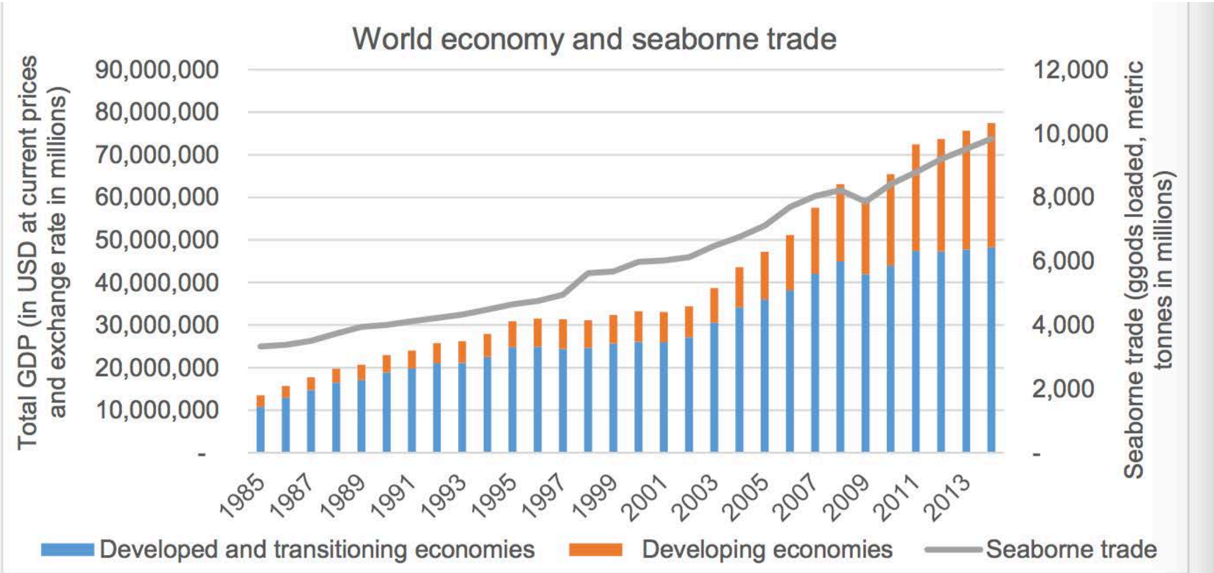

Figure 1. World Economy and Seaborne Trade, 1985-2014(UNCTAD, 2015a; UNCTAD, 2015b)

On the other hand, continuing seaborne trade also means high potential maritime safety risks. Among others, thanks to the technological advances and the strengthened system of global maritime governance especially by IMO (Figure 2), marine casualties and incidents have not increased with the improving contributions to the economy and have maintained at a stable level or have even declined a little in recent years. (Figure 3)

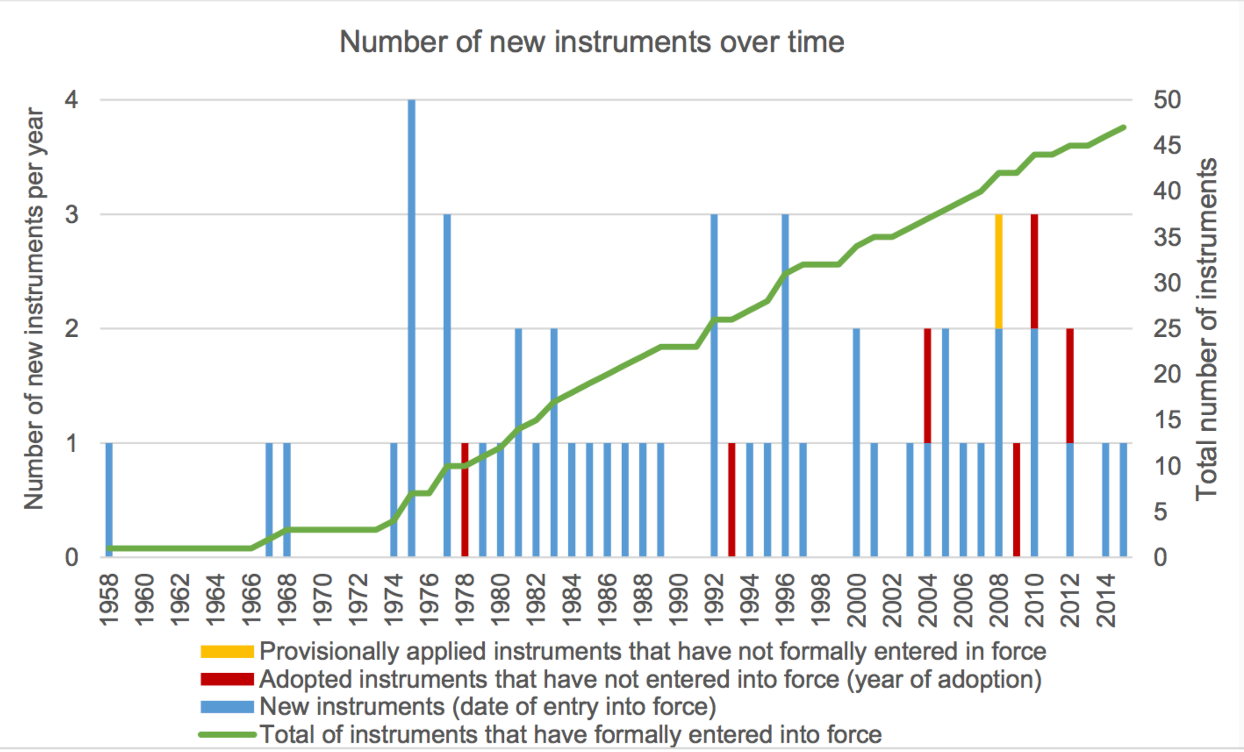

Figure 2. Instruments over Time (IMO, 2016a)

IMO's main objective is to strengthen the system of global maritime legislation for all nations involved in international shipping. As the only forum in which to develop global regulation that can be uniformly applied, IMO developed an increasing number of instruments to assure the safe and environmental navigation especially in recent years. Figure 2 illustrates the yearly and cumulative number of different instruments from 1958 up to 2014. These instruments contributed to maritime safety among the member states, official maritime industry associations and other stakeholders.

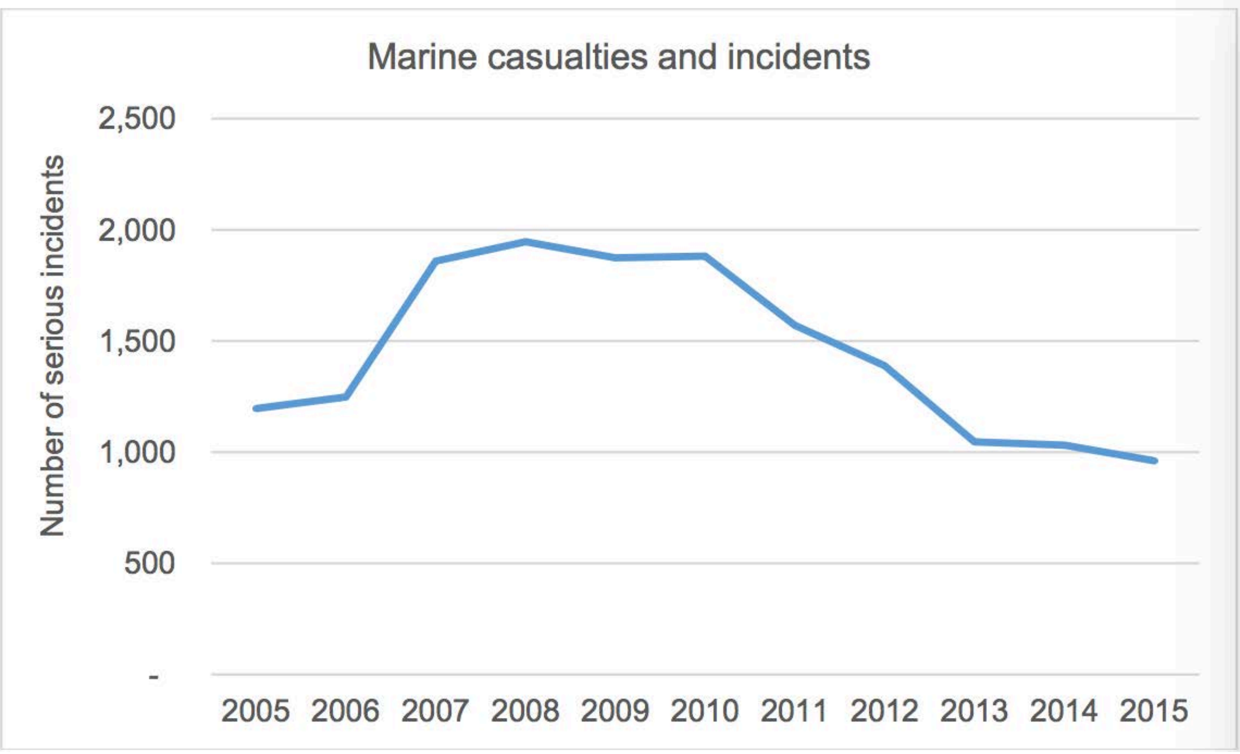

Figure 3. Marine Casualties and Incidents (IMO, 2016b)

Admittedly, IMO instruments regulate international shipping and domestic ships do not necessarily need to follow this regime, except national authorities and administration implement those rules and regulations also to national domestic shipping. Different countries have found different approaches to regulate the non-convention vessels. China, for example has made a great contribution in its economic growth in recent years and waterborne trade has played a vital role in improving national economy. Besides paying the attention towards the development of waterborne transportation, China has also undertaken steps to enhance maritime safety by issuing regulations on the safety management of inland waterways on the sidelines of IMO regulations. Training mechanisms for mariners have been augmented by developed and applied new technologies in domestic waters. Statistics for the most important inland river of Changjiang indicates steady decline in marine casualties and incidents in recent years. (Figure4).

Number of marine casualties and incidents in Changjiang 2010-2014

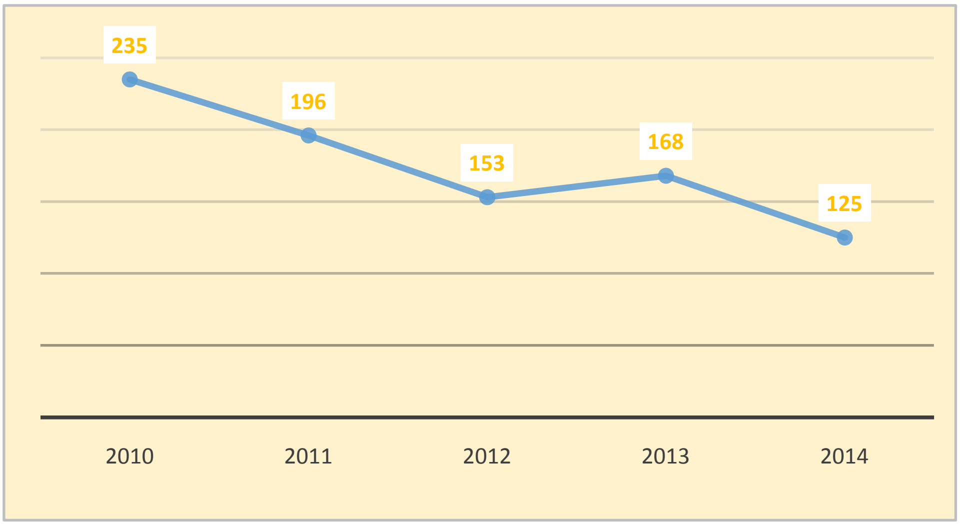

Figure 4. Number of marine casualties and incidents in Changjiang 2010-2014

Source: State of Administration of Work Safety

However, compared with the IMO regulatory framework vessels, the regulations for non-convention ships are often not as elaborate and highly developed as the IMO general safety and environmental protection regime. Potential risks are much higher due to the lower standards and less qualified crew. Eastern Star accident was reflection of such standards that occurred on 01 June 2015 resulting in 442 deaths. Dramatically, a similar accident of the Sewol ferry took place in Republic of Korea a year before the Eastern Star casualty. Ferry Sewol sank in the morning of 16 April 2014, on a route from Incheon to Jeju resulting in 304 deaths including passengers and crew.

These accidents highlighted negligent behaviour of respective governments and administrations and also frustrated the confidence of worldwide maritime safety. Thus, it is pertinent to identify and analyze the causes, and especially the human factors leading to the two Asian casualties in order to avert occurrence of such disasters along with improvement of maritime safety of non-SOLAS ships in the future.

2.2 Literature review

As required by the Casualty Investigation Code (CIC) (IMO, 2008) and implemented by the majority of States, the accident investigation, among numerous approaches to be applied to improve safety performance on board, is one of several widely utilized approaches to achieve safety (Harms-Ringdahl, 2004). According to Harms-Ringdahl's argument, accident investigation is the "collection and examination of facts related to an occurred specific event". Along with this useful and positive function, most major improvements or modifications to a maritime legislative system, criticized as the "disaster-driven system", are often carried out after lessons learned from major accidents (Jalonen & Salmi, 2009). Additionally, in accordance with risk assessment, analysis of an accident plays an indispensable role for setting priorities and identifying hazardous sources (Svedung, 2000). However, most of the current maritime accident investigation systems encourage investigators to determine what happened during an event and how the event occurred, rather than why the event occurred (Lee N., Donald K, & Randal L, 2005). This is often coupled with the lack of knowledge and appreciation for the organizational context in which human error is made (Schröder, Baldauf & Ghirxi, 2009). To shun negative influence, a better understanding and workable analysis causation model to direct accident investigation methodology is an alternative need. (Kim, Nazir, & Øvergård, 2016)

Several authors (e.g., Reason, 1997; Rasmussen, 1997), while discussing the ''safety space", based on their theories, have argued that socio-technical systems tend to drift toward states of higher risk. The performance of the actors within a socio-technical system is always constrained by the surroundings, e.g., administrative, competitiveness, economic benefits and safety related constraints, thereby creating a small space of freedom for designers, operators, and managers to perform their work tasks with little considerations given to the feasibility and consequences (Rasmussen, 1997). Thus, accident analysis should incorporate the circumstances that induce variation in behaviors as well as the dysfunctional interactions among correctly operating components. Several accident analysis models e.g., Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012), Swiss Cheese Model (Reason, 1990; 1997; 2008), AcciMap

(Rasmussen, 1997), have been developed on the basis of the systems approach (Underwood and Waterson, 2013).

Chinese scholars have researched on risk management, accident investigations, policies, and suggestions and so on at the domestic level. They have tried to summarize some basic characteristics of the risk management in water transportation through the statistics of accidents that have happened in recent years (Li, 2007) and present an anticipation of accident (Chen, 2002). Some have focused on accident analysis in a certain areas, such as Shanghai (Zhang, 2013), Zhoushan (Xu, He&Lv, 2008), Xiamen (Wang, 2006) and Beihai (Long, 2012) and provided some countermeasures to prevent risks from the view of legislation, the emergency response system and infrastructure improvements. The risk management in Ro-Ro passenger ships was also a popular researching aspect especially after the “11.24”[1] marine disaster of China. (Zhang, 2010) Some others introduced updated regulations of the IMO and their effects on Chinese passenger ships (Liu, 2010). Also researches related to the spot supervision (Chen&Zhang, 2007), status analysis (Quan, 2010), safety management (Li&Jin, 2009) and safety assessment (Hong&Yu, 2000) as well as safety management from governmental view (Liu, 2002) on Ro-Ro passenger ships. Research has been undertaken in the safety management of passenger ships in domestic waters on the aspects of supervision on tour ships (Liu, 2015), human factors (Zhang, 2001), technological analysis (Zhang, 2014), small ships management (Ji, 2015) and so on. Relevant research on maritime management from the public’s service view (GAO, 2011), construction of the maritime wet (Han, 2011) and maritime management (Yu, 2008) were also considered by scholars.

Post Sewol accident, few Chinese scholars carried out researches on the accident and provided recommendations. Cause analysis on the Sewol was discussed in various articles (Wu, 2014) and (Li & Wu, 2014), which was also made in 2015 (Mi &Zhao, 2015). Further discussions about

[1] The Ro-Ro passenger ship “ Dashun”, owned by Yantai Ferry Company of the Shandong Province, capsized on 24 November 1999 while navigating around the sea areas of Yantai (a city of Shandong Province) leading to fatal consequences with 280 deaths and an economic loss of 90 million RMB.

human factors in the accident (Guo, 2014), influence to the maritime safety regime of the Republic of Korea, search & rescue (Xu, 2015), legal view (Wang, 2015) and references for China government from the accident (Wang, 2015) were developed by Chinese scholars.

Despite of above research and discussions, the underlying causes of the Eastern Star needs to be identified and analysed in order to acquaint with the situation and issues of Chinese maritime safety management in inland waterways by using a schematic approach. In addition, it is also imperative to compare the Sewol and Eastern Star accidents to learn more from these tragedies and avoid the occurrence of similar accidents in the future.

2.3 Objectives of the study

This study attempts to achieve the following objectives:

(1) Analysis of the maritime safety situation of the inland waterways of China.

(2) Providing detailed narratives of the Eastern Star and Sewol accidents in detail.

(3) Explaining how AcciMap can contribute to identification of causes and its application in analysing failures of the two Asian accidents.

(4) Comparing similarities and differences in the two Asian casualties.

(5) Providing recommendations in the maritime safety management for non-SOLAS passenger ships especially for the Chinese government's reference.

2.4 Limitations of the study

There are two main limitations to this study. The first concerns the materials sources. It is difficult to make an objective evaluation about the two casualties due to the limited information achieved from investigation reports. The Eastern Star accident occurred in the year 2015 and therefore a very scarce academic analysis is available for reference. Secondly, numerous departments were involved in the casualty making it more multifaceted. It is difficult to give a complete and accurate description of the relationship. A detailed investigation report for accident of ferry Sewol was published but in local language and English version available from English website was limited. Hence, it poses a great challenge to make an accurate evaluation when depending on second-hand data and materials.

The second limitation lies in the approach itself. It is critical to choose a suitable model to analyse the causes since every model has its advantages and disadvantages. Though AcciMap has the advantage in most aspects concerning this study, however, disadvantage exists in terms of the quality of the analysis. Analysis depends on the quality of accident reports that is subjective since AcciMap analysis does not provide a method to develop corrective measures.

2.5 Study Plan

This dissertation is mainly divided into seven main chapters. The first chapter begins with a preliminary explanatory background of the topic giving the motivation and objectives for the research. Factual information of the two Asian casualties of Eastern Star and Sewol is described separately in Chapter Two. Chapter Three introduces the methodology of AcciMap used in this study. The application of AcciMap in the two casualties of Eastern Star in China and Sewol in the Republic of Korea is illustrated in Chapter Four. Chapter Five involves comparison of the two Asian accidents. Chapter Six elaborates about findings and further discussions. The concluding parts are placed in Chapter Seven followed by recommendations on non-SOLAS ships risk management for the reference by governments in the future.

2 Factual information of the two Asian casualties

2.1Factual information of the Eastern Star Casualty in China

2.1.1Casualty brief

At 21:30 on June 1, 2015, the Eastern Star Cruise, owned by the Chongqing Oriental Steamship Company enroute from Nanjing to Chongqing encountered a severe thunderstorm and capsized in short span of time while navigating in the middle of the Yangtze River in the Jianli waters of China. On 13 June, a total of 442 deaths were confirmed and only 12 persons were rescued. It was the deadliest peacetime maritime disaster in China's history and the worst since the Taiping steamer sinking in 1949, which killed over 1,500 persons.

The Eastern Star was a river cruise ship operating in the Three Gorges region of inland China, constructed in February 1994 and retrofitted in 1997, 2008 and 2015. The inclement weather was cited as primary reason by the investigation report issued at the end of year 2015.

2.1.2 Particulars of the ship

Table 1. Particulars of the Eastern star ship

Name of ship	Dongfangzhixing, Translated as Eastern Star
Type	Cruise ship
Length	76.5m
Beam	14m
Extreme Vessel Breath	12.4m
Height	18.6m
Depth	3.1m
Draught	2.5m
Load Draught	2.16m

Tonnage	2200
Full load displacement	890.602
Rated Power	441.00kw ×2
Capacity	534
Capacity of Crew	50
Registered owner	Chongqing Eastern Shipping Corporation
Manager	Same with the owner

The Eastern Star was a pointed stern steel ship with double bottoms (See picture 5) and was first built in 1994 by the Chuandong shipyard. When departing from Nanjing port, the ship was equipped with an AIS (B), a GPS, a tester, 2 navigation radar, a ECS and 3 searchlights as well as 2 VHF radiotelephones, 2 portable VHF radiotelephones and a set of external PA.

Figure 5. The full image of Eastern Star

Source: Wikipedia

2.1.3 Ship certifications

After investigation, the certificates of the Eastern Star were deemed complete and valid. The certifications held are listed as follows:

- Certificate of nationality of the ship,
- Ship minimum safe manning certificate,
- Inland vessels airworthiness certificate,
- Rivers and Three Gorges ship sailing certificate,
- Inland vessels Sewage Pollution Prevention Certificate,
- Inland Ship Oil Pollution Prevention Certificate,
- Inland Tonnage certificate,
- Inland load line certificate,
- Inland passenger ship certificate,
- Document of Compliance (copy),
- Safety Management Certificate.

2.1.4 History of the voyage

The cruise Eastern star departed from the eastern city of Nanjing and was sailing to Chongqing in the southwest via the Three Gorges - a journey of approximately 1,500km (930 miles). The Eastern Star departed Wumadu pier of Nanjing Port on 28 May 2015 at 1300 hours and sailed upstream in the Yangzi River. Estimated Time of Arrival (ETA) to the destination Chongqing Port was at 0630 hours on 07 June 2015. The status of the Eastern Star during sailing is listed as follows.

- Crew: 46,
- Passengers: 398,
- Fuel oil: 30 tons,
- Fresh water: 17 tons,
- Ballast water: 3 tons,
- Forward & aft draught: 2.10 meters, even keel.

Table 2. Logbook of the Eastern Star

Time	Event
2103	Navigated to the water area around “No.1 Buoy of Tianzi”. Ship speed 14 km/h. Lighting and drizzling.
2121	Maximum wind speed 24.6 m/s (Bf 10). Low visibility. Captain ordered to Chief Officer (C/O) to slow down speed, altered small rudder angle to port, and intended to anchor in the water area near the starboard side of the river. Ship speed 12.0 km/h.
2123	Ship speed 2.2km/h, and gradually reduced to 0.
2124	Ship started to go astern due to the influence of strong wind. Ship speed 4.0 km/h astern.
2125	Ship speed 5.6km/h astern. Captain ordered C/O to increase the engine speed.
2126	Ship speed reduced to 5.0 km/h astern. Suddenly encountered downburst storm, the maximum wind speed increased to 32-38m/s (Bf 12-13).
2129	Ship speed reduced to 4.0 km/h astern by the effects of the engine and rudder.
2130	Ship started to turn and wind angle increased under the effect of the strong storm. The ship was not under control. Ship speed increased to 6 km/h astern. Later on, the ship suddenly listed to starboard and started to flood.
2131	Main engine stopped. Heavily listed to starboard.
2132	The Eastern Star Capsized. AIS and GPS signals disappeared.

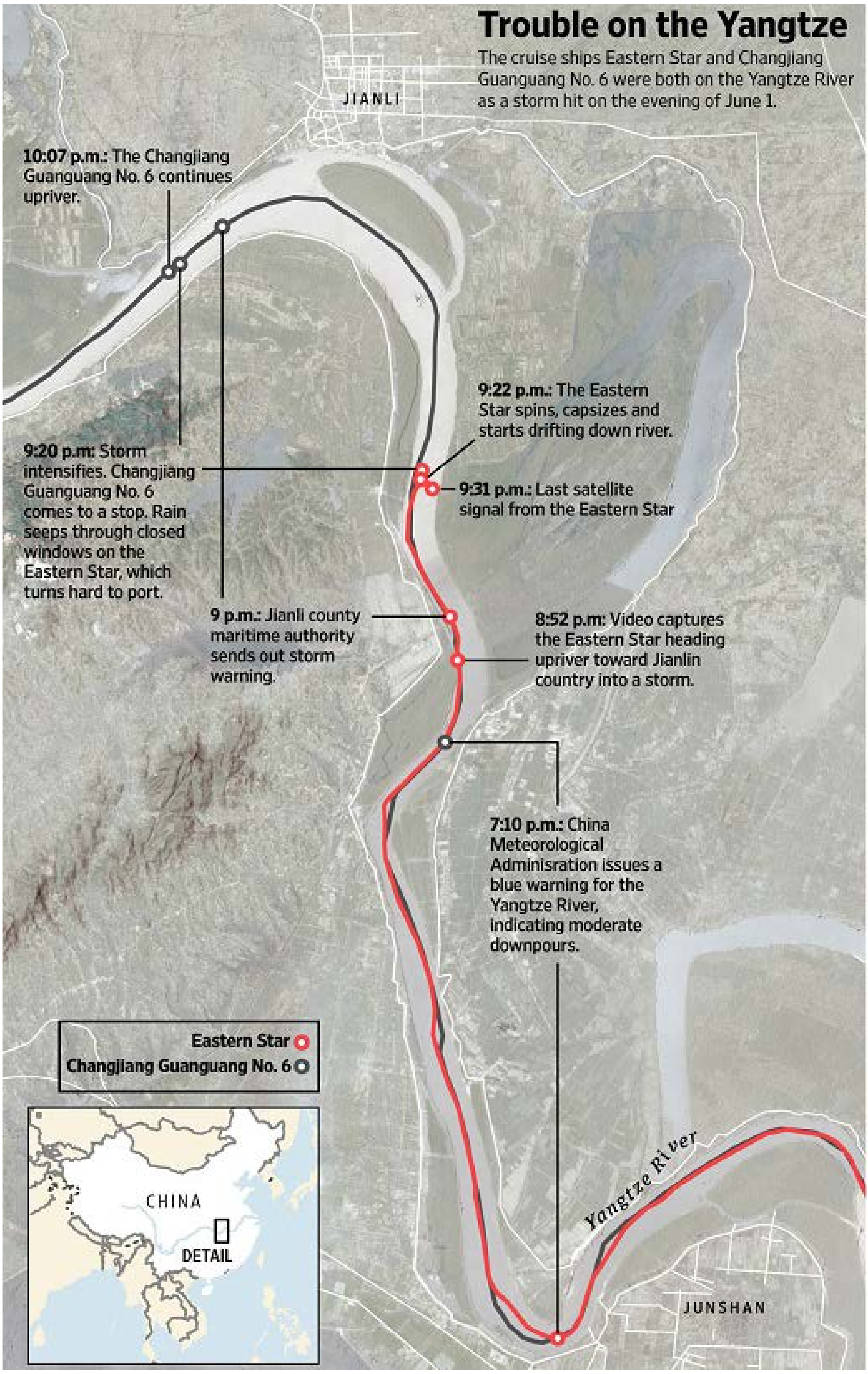

Figure 6. The sinking timeline of Eastern star

Source: Chinese Ministry of Transport satellite data

2.1.5 Environmental conditions

A squall line system appeared "above the waters where Eastern Star" navigated accompanied by a downburst, tornadoes, other short-term local heavy rainfall as well as severe convective weather at the time of accident and therefore the ferry capsized suffering strong storms.

The hydrology report indicated that no shallow patches, obstacles, Malaysia Island riverbed morphology were found and the Shoal pattern was basically stable with a smooth flow.

2.1.6 Search and Rescue (SAR)

SAR operations were launched immediately for saving passengers and crew. The operations reached full scale about twelve hours after the accident. SAR operations were observed from highest echelons in the Government directly from Communist Party General Secretary Xi Jinping and Chinese Premier Li Keqiang. Rescue efforts were overseen personally by Premier Li Keqiang, Vice Premier Ma Kai and State Councillor Yang Jing. 82 people were confirmed dead by 04 June, with few bodies washed ashore 50 km (31 mi) downstream from the wreck. Ship's captain and engineer were rescued along with 12 people in the immediate aftermath.

2.1.7 Summary

On 01 June 2015, at 21:30 Beijing Time, the passenger cruise Eastern Star capsized immediately after encountering a severe thunderstorm when navigating in the Jianli waters of Yangtze River of China. 442 deaths were confirmed in the disaster. According to the investigation report, inclement weather was the main cause of the casualty. However, 45 persons who came from 12 departments were punished due to their liabilities.

2.2Factual information of the Sewol Casualty in the Republic of Korea

2.2.1 Casualty brief

The sinking of the ferry Sewol occurred in the early hours of 16 April 2014, enroute from Incheon to Jeju in the Republic of Korea. Ferry had embarked 476 passengers that included mostly students from secondary school, Danwon High School (Ansan City). Distress signal was passed by vessel at 0858 hours (Korea Standard Time) from a range of 2.7 km (1.7 nm) north of Byeongpungdo. 172 people were rescued during SAR efforts and fishing boats and other commercial vessels rescued more than half of them. The Republic of Korean Coast Guard vessels arrived on scene approximately 40 minutes after the accident. In all, 304 passengers and crewmembers lost their lives in the disaster.

2.2.2 Particulars of the ship

Table 3. Particulars of the Sewol

Name of ship	MV Sewol
Type	RoRo passenger ferry
Builder	Hayashikane Dockyard Co., Ltd, Japan
Year	1994
Class	Korean Register of shipping (since 2012)
Port of registry	Incheon, the Republic of Korea (since 2012)
Gross tonnage	6825 GT
Length over all	145.61m
Beam	22.00m
Depth	6.25m
Load Draught	2.16m
Maximum speed	22kn
Capacity	956 persons (921 passengers +35 crew), 180 vehicles and 154 regular cargo containers.

The Sewol was a Ro-Ro ferry built by the Japanese company Hayashikane Shipbuilding & Engineering Co. Ltd. in 1994. The ferry was capable of carrying 956 people onboard including crew. It had a legal carrying capacity for 180 vehicles and 154 regular cargo containers. The maximum designed speed of the ship was 22 knots (41km/h; 25mph). The ship formerly belonged to Japan Oshima Transport Co., Ltd. (headquartered in Kagoshima Prefecture). Chonghaejin Marine purchased the ferry in 2012. It was renamed as Motor Vessel (MV) Sewol that was 18 years old and dilapidated. Initially it was named as Ferry Naminoue and was operated as a transport ship for cargo and passengers by the Japanese company A-Line Ferry from 1994 to 2012. Thereafter it was registered by Chonghaejin and underwent modifications from 12 October 2012 to February 12, 2013. These modifications were later found to be based on an illegal redesign of the ship.

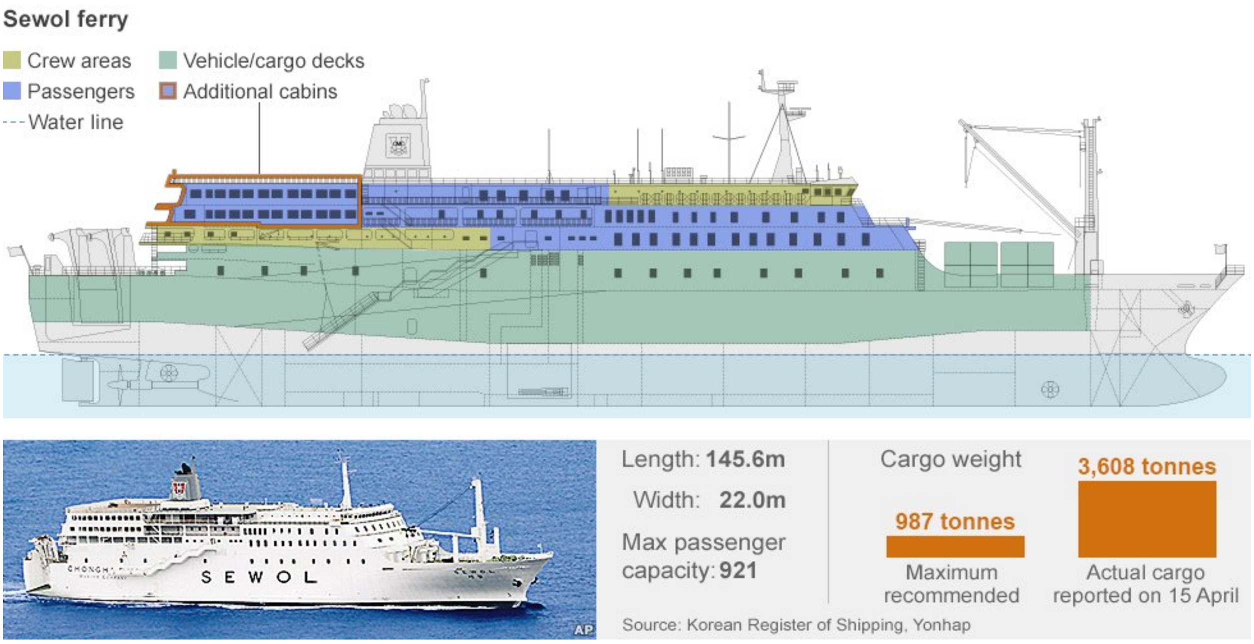

Figure 7.The image of Sewol ferry

Source: Korea Register of shipping, Yonhap

2.2.3 Sinking description

Table 4. Sewol sinking description

Time	Event
0800	The 25-year-old third mate, Park Han-gyeol, began her scheduled four-hour shift on the bridge.
08:48	Right before 8:48 a.m., Cho steered the ship on a course of 135 degrees, or southeast. At 8:48, Third Mate Park, who was monitoring the radar and radio in the ship, came to conclusion that there was another ship approaching on a collision course and therefore ordered to Helmsman Cho to turn the ship, initially by 5 degrees to 140 degrees and then to 145 degrees. Cho reacted to Park's orders and turned to starboard to 145 degrees.
0849	The second turn to course 145 (10 degrees) in one second, from 8:49:12 to 8:49:13, is contemplated to be sharp in the context that generally large passenger ships would take two minutes to make a five-degree turn. When the chief engineer was enquired about the situation, Cho replied that the "steering gear was not working." Due to the imbalance, Park ordered Cho to balance the ship to "Port," but this order was misheard as a Korean word meaning to 'turn in the opposite direction,' a mishearing that did not affect the meaning. The chief engineer testified that the ship commenced tilting precisely after Park's last order.
0850	The chief engineer ordered an evacuation of the engine room through a call to the assistant engineer. With the engines off, Sewol became unable to change directions and began drifting sideways.
0852	Choi Duk-ha, a Danwon high school student aboard the ferry at 8:52 a.m., made the first emergency call; he called the national emergency service number and reported to the Jeollanam-do fire station that Sewol was capsizing.
0855	At 8:55 a.m., Sewol's crew made their first distress call to the Jeju vessel traffic service requesting them to notify the Coast Guard since the ferry was rolling and in danger.
0930	Around 9:30 a.m., the captain ordered to abandon the ship, though the order may not have been relayed to all the passengers.
1118	At 1118 hours approximately, the bow of the ship was submerged, with a section of the hull about 2 meters (6 ft. 7 in) high and 20 to 30 meters (66 to 98 ft.) long showing above the water.

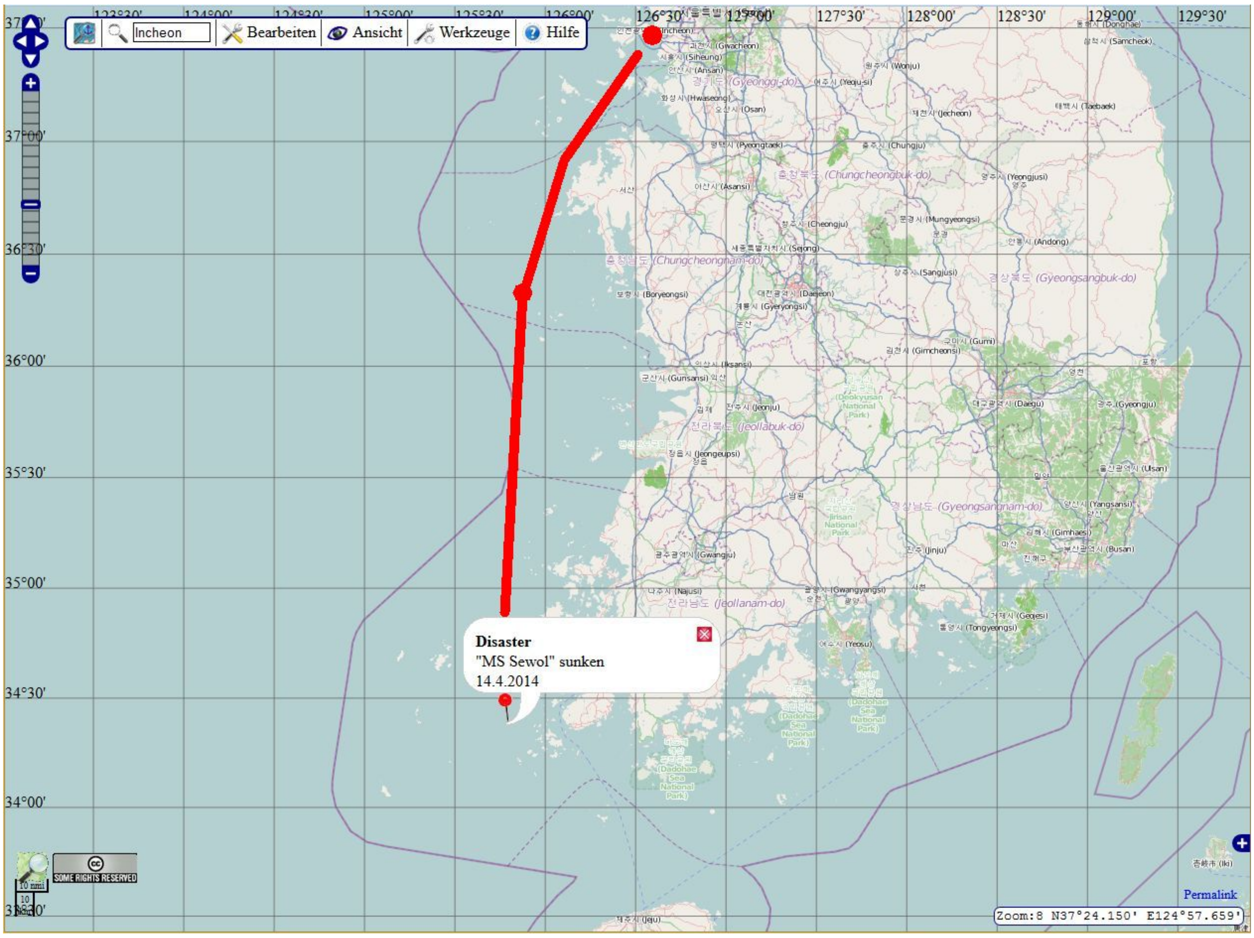

Figure. 8 The route of Sewol ferry (Source: Wikipedia)

2.2.4 Captain, crew and passengers

The crew made seven phone calls with staff from Chonghaejin Marine. The passengers were instructed to stay in their cabins while the captain and crewmembers abandoned the ship. The captain, chief engineer and the chief and second mate were the first one to be rescued. The captain was rescued at approximately 0946 hours. As the ship capsized, some passengers followed the announcements to stay put, even as the water came in. Most of the student passengers obeyed the announcements. Some passengers who climbed to the top of the ship or jumped into the water were rescued. Videos recorded by passengers during the capsizing were recovered. The recordings included announcements instructing passengers to stay in place and put on life jackets, while some videos showed passengers joking around, putting on life jackets and bidding farewell.

Passengers made calls, sent text messages and KakaoTalk mobile messages during the capsizing of ferry. The last message was sent at 1017 hours. Text messages and social media posts allegedly made by survivors after the capsizing were circulated in the media, but an investigation by the Cyber Terror Response Centre found that passengers did not use their phones between 1200 hours on 16 April and 1000 hours on 17 April. All the reported survivors' messages were termed to be fake.

2.2.5 Search and Rescue

The SAR activities are extracted from the accident investigation report and summarized in the Table 5 (see next page).

Table 5. The SAR activities for Sewol

Time (Korea Standard Time)		SAR activities
16th of April	8:58	Sewol started to flood and sinking. Korea coast guard (KCG) receive information from one student's parent
	9:00	Sewol sent out the SOS alarm, KCG sent out rescue team
	9:30-9:40	Ship from KCG arrive the site of accident following by helicopter. Some commercial ships joined the SAR. Sewol capsized and sinking, 90% of the ship was flooded.
	10:00-10:20	About 120 passengers were rescued
	10:55	Korea Navy sent out about 20 ships and one helicopter to rescue. Korea Air force sent out 46 lifeboats by transport aircraft.
	11:00	Sewol almost sank into water totally.
	14:00	Professional rescue people arrived.
	15:00	USA Navy arrived; however, the rescue was interrupted due to the bad weather and lack of lighting at night.
	17:00	16 helicopters and 24 ships joint the SAR. Fishing vessels in the vicinity also joint.
	20:00	Underwater SAR was interrupted due to the bad weather.
17th of April		Flare burst was used by KCG to restart underwater SAR. Ship and helicopters from Navy arrived. Divers cannot enter into ship as the low visibility underwater. 280 passengers still missing.
18th of April		The bow of the Sewol sank into the water. Divers successfully entered into ship.
19th of April		3 dead bodies were rescued at the first attempt of entering into the ship
The Korea government and civil groups conducted the following SAR activities.		

2.2.6 Summary of the Sewol accident

On 16 April 2014, the Sewol capsized and sank 1.5 kilometres (0.93 mi) off Donggeochado, and the south Jeolla Province. Sewol was on the passage from Incheon to Jeju. A total of 304 people were killed in the accident.

The Government's Board of Audit and Inspection of the Republic of Korea revealed that Korean Register's licensing was based on falsified documents. The amount of cargo carried was twice as the legal limit. Investigation into accident revealed that the ship was carrying 124 cars, 56 trucks, and 1157 tons of cargo.

2.3 Conclusions derived from of the two accidents

From the factual information, except for the bad weather, illegal modifications on the ship, loopholes in the management regime of the ship company and the inadequate surveillance from all levels of administrations were the main contributing factors to the Eastern Star accident. Coincidently, the Eastern Star and the Sewol accidents had some major common aspects. They both occurred on domestic ships and resulted in tremendous number of deaths. Both ships caught in the accidents were initially constructed in 1994 and were retrofitted several times. The long-time of sea service and illegal modifications of the two ships, combining with unfavourable external factors, caused the tragedies.

3 Methodology of the study

3.1Background

Derived from UNCLOS, there are a number of IMO conventions requiring administrations to investigate any casualty that ships flying their flag. Among others, there are the SOLAS regulations I/21, MARPOL and Load Lines Conventions, warranting investigations to provide the findings from those investigations to the organisation. The new Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code) was adapted at the 84th session of the MSC in May 2008 and entered into force on January 2010. The basic idea of Code is to identify the necessary changes of existing rules and regulations that are supporting a repetition of an accident that resulted in the death, damage to the marine environment and/or total loss of a ship. Accident investigations and the improvement of rules and regulations are expected to contribute to changes in systems and processes to bring them up to a higher safety level. Same principles should be applied to the ships not governed by IMO rules concerning safe navigation and protection of marine environment in domestic waters.

It entirely depends on investigators how they investigate any marine accident, since there are a variety of different and maybe even competing investigation methods. It seems to be worth to research if the use of a harmonized approach to accident investigations can improve the safety and efficiency of maritime transportation. Existing approaches to accident investigations are typically based on models – as e.g. sequential like fault trees or models that consider the organizational context like Reason. These models are linear and have been found not to be sufficient enough and result in system approaches. The recently developed and introduced AcciMap method is somewhere between a linear organizational model and a system approach. In this chapter studies will be carried out in order to find out about the advantages, potentials but also shortcomings and or lack of AcciMap approach to meet the aims declared by IMO. These investigation methods can also be made applicable in analysing accidents in domestic waters.

Based on Rasmussen's risk management framework, AcciMap (Rasmussen 1997) is a systems-based accident analysis method used to graphically depict the decisions, actions and failures that contributed to the accident under analysis, along with the relationships between them. AcciMap considers failures by operators on the front line and also failures at the higher company management, local authority and governmental levels.

Another graphical method, Fault Tree Analysis (FTA) is used to graphically depict the failures involved in accident scenarios. Using tree-like diagrams, failure events are described along with their human – and hardware – related causes.

Inspired by Reason's Swiss cheese model, the Human Factors Analysis and Classification System (HFACS; Wiegmann and Shappell 2003) is a systems-based accident analysis method, originally developed for aviation accident analysis purposes but since applied in a range of domains, that provides analysts with taxonomies of failure modes across four organisational levels (unsafe acts; preconditions for unsafe acts; unsafe supervision; and organisational influences). Working backward from the immediate causal factors, analysts classify the errors and associated causal factors involved across the four levels using the taxonomies provided.

Viewing accidents as a control problem, Leveson's STAMP model (Leveson 2004) focuses on control failures across the overall work system. STAMP considers various forms of control, including managerial, organisational, physical, operational and manufacturing-based controls and provides analysts with taxonomy of control failures (Leveson 2009). STAMP also uses systems dynamics to investigate the causes of the control failures identified.

Social Network Analysis (SNA; Driskell and Mullen 2004) is used to understand network structures via description, visualisation and statistical modelling (Van Duijn and Vermunt 2006). When used for accident analysis purposes SNA is used to evaluate the communications failures involved or problems within the social network (e.g. overloaded nodes or communications bottlenecks). SNA produces social network diagrams, which depict the connections between entities during scenarios of interest. Statistical modelling is then used to analyse the networks mathematically in order to quantify aspects of interest.

The propositional network methodology was originally developed for modelling situation awareness in complex socio-technical systems (Salmon et al. 2009) and has since been used to model the situation awareness-related failures involved in accidents (e.g. Griffin et al. 2010). Networks representing situation awareness are constructed and situation awareness failures (e.g. lack of awareness, erroneous awareness and failure to communicate key information) are identified through network analysis procedures.

Critical Path Analysis (CPA; Baber 2004) is used to model the performance time associated with sequences of tasks and has previously been used to model operator response times during accident scenarios (e.g. Stanton and Baber 2008). CPA works by modelling task sequences and calculating, using standard human response time data and the time required for completion of different sequences of tasks.

The Technique for the Retrospective and Predictive Analysis of Cognitive Errors (Tracer; Shorrock and Kirwan 2002) is both an error prediction and retrospective error analysis method having previously been used for the analysis of air traffic control and rail accidents. Tracer uses six error taxonomies to investigate the operator errors involved, including the errors themselves, performance shaping factors, error detection and recovery strategies.

Unlike the individual methods described above, the Event Analysis of Systemic Teamwork framework (EAST; Stanton et al. 2005) is an integrated suite of methods used to analyse activity in collaborative systems. EAST uses a combination of methods to describe the task, social and knowledge networks underlying collaborative activity, including task analysis, social network analysis, network analysis and teamwork assessment methods. Recent applications (e.g. Rafferty et al, In Press) have involved using the approach to model accident scenarios.

As listed above, there are a variety of different investigation methods like FTA, HFACS and STAMP and they take the advantages in the accident investigations for some cases. After comparing with the features of these methods, AcciMap is a harmonized approach to analyse the organizational factors and is the most applicable one for this research in the causes identification and recommendations suggestion.

3.2AcciMap and its features

The AcciMap method (Rasmussen, 1997; Svedung and Rasmussen, 2002) is an accident analysis technique based upon the notion that there are multiple levels of causality involved in accidents, as put forward in Rasmussen's (1997) model of risk management. The method presents a graphical portrayal of factors within the system that impact the occurrence of an accident. Typically, the following six levels of complex socio-technical systems are considered (although these can be modified to suit analysis needs): government policy and budgeting; regulatory bodies and associations; local area government planning and budgeting (including company management); technical and operational management; physical processes and actor activities; and equipment and surroundings. Levels 1–4 represent all of the decision-makers that may have been involved in the accident scenario, described by levels 5 and 6, through the decisions they make in their normal work context (Woo and Vicente, 2003). AcciMap analysis focuses upon the causal relationships between these levels that allows for a vertical analysis across the levels of a system rather than the horizontal generalisation within individual levels normally found in accident analysis methods (Svedung and Rasmussen, 2002).

A generalization aggregating accidental courses of the events set is represented by a cause-consequence chart. Predictive risk analyses are widely based on these charts (Leveson 1995). The choice of the critical event reflecting the release of a well-defined source of hazard for example “loss of control of accumulated energy” or “loss of containment of hazardous substance”, defines the choice of set to include in a cause-consequent chart. The causal tree (among potential causes, the logic relation) is connected by the critical event with a consequent event tree (the possible temporal and functional relation among events) clearly reflecting the switching of the flow as a result of automatic safety systems or human decisions (Rasmussen & Svedung 2000). Controlling the hazardous process at the socio-technical system’s lowest level is this analysis’ focus, as shown in the figure below (Qureshi, n.d.)

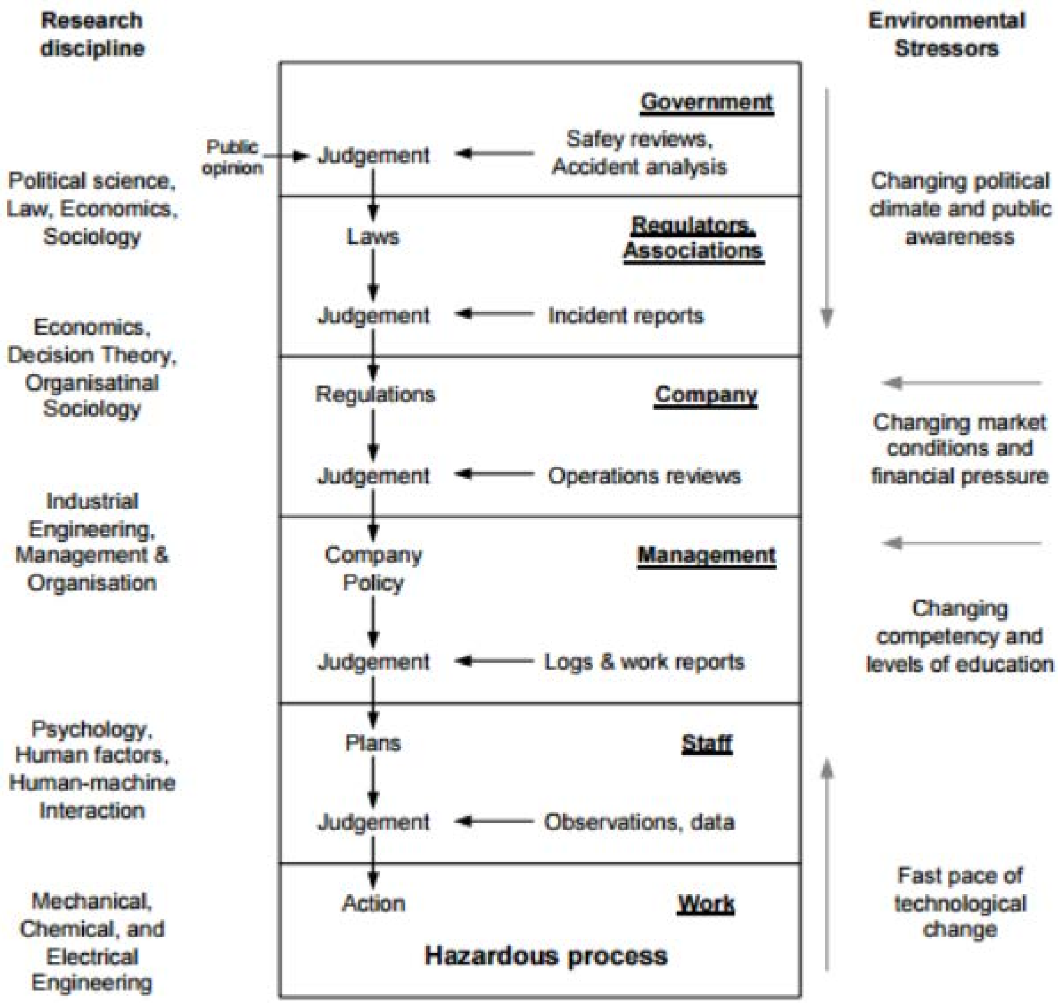

Figure 9. The socio-technical system involved in risk management (Rasmussen, 1997) Source: (Sklet, 2002)

Each method has its own advantages and disadvantages in analysing the cases of accident. AcciMap shows the causal relations obtained between different technical, psychological, organisational, cultural, regulatory, legal and other factors, each of which domains typically have their own methods of explanation (for example, psychology does not follow physical laws; organisational behaviour is explained using largely different concepts from those of individual psychology and regulatory principles are often different from all of those). As one graphic method, AcciMap has been very effective in creating an overview of complex occurrences and for the communication of assumptions and findings within a risk analysis and design team. Moreover, AcciMap serves to identify relevant decision-makers and the normal work situation in which they influence and condition possible accidents. The focus is not the traditional search for “management errors” and the like. Therefore, the AcciMap representing the conditioning system of one particular accident is well suited as a “conversation piece” to support discussion with the relevant decision-makers. The basic AcciMap represents the conditioning system and the flow of events from one particular accident. Suggestion of improvements by changes identified from this map will therefore very likely be ad hoc. A generalization is necessary based on a set of accident scenarios.

As every coin has two sides, the features of AcciMap can be illustrated as follows from its strengths and limitations.

Strengths:

(1) An AcciMap is intuitively easy to understand. It is based on a sound theoretical model and is simple to learn and use.

(2) An AcciMap representation requires the analyst to consider all factors in various levels in the organizational model and explicitly to check to see what the causal relations between any factors in different levels of the model might be. Causal connections are thus observed which might be missed if the domains in the organizational model are considered separately.

(3) AcciMap enables identification of system-wide errors leading to the occurrence of the accident at the sharp end. The complete accident aetiology is exposed.
(4) Its output offers an exhaustive analysis of accidents and incidents.
(5) It provides a clear visual interpretation of the accident aetiology.
(6) It is a generic approach that has been applied across many domains.
(7) Considering the different levels involved in the accident, it enables an extended timeline of causality to be established.
(8) It focuses on systematic improvements rather than focusing on blaming individuals. (Salmon, 2011)

Limitations:

(1) The counterfactual condition used to determine causality is informal; it is not provided with formal semantics. Thus, it is dependent on the intuition and personal judgement of the investigator.
(2) There is no criterion to determine whether an organizational model is adequate; the model comes from outside the analysis.
(3) The level of generality of the factors expressed in the nodes is high; they can be very abstract. An attempt to derive countermeasures is correspondingly vague.
(4) The AcciMap method provides only a weak analytical approach to physical failures or identifying inappropriate features of the physical part of the system.
(5) An AcciMap does not represent the results of a causal analysis by itself. It requires a textual expression of the results and serves to illustrate or summarise that text.
(6) The result of an AcciMap analysis is relatively lightly constrained; it is thus possible to derive different AcciMap of the same incident showing different sets of causes, depending on the analyst's focus. (Salmon, 2011)

3.3Summary

AcciMap is one of the major graphic methods in accident analysis, although it has several limitations. AcciMap requires as many factors as the analyst can consider so that the causal connections are observed in a simple and clear way. It will serve to identify the decision-makers having a potential for improving safety and to support communication with the various disciplines relevant for cross-disciplinary cooperation in research and design. Compared with other models, AcciMap has the advantage in the organizational factors analysis and also is easy to understand.

4 Application case studies

4.1Introduction

As discussed in above chapters, AcciMap is a method somewhere between a linear organizational model and a system approach, which takes advantage of organizational factors in accident investigation. Though the accidents did not happen on the ships under IMO's regime, the approach itself should, nevertheless, be effective. In this research, organizational factors in the Eastern Star and Sewol accidents will be identified and analysed carefully in order to identify weaknesses in domestic marine safety management. After a comparison of accident analysis methods, AcciMap was chosen for application to the two accidents for its strengths in serving the research purpose.

In order to explain the AcciMap and test its application to the accidents, several workshops were organized during this research. On June 8, the first workshop focusing on the AcciMap and its possible application to the Eastern Star casualty was held in WMU. Two Professors and two researchers from the MARISA Group and three students participated in the seminar. After an introduction to the AcciMap and a brief description of the Eastern Star casualty, the possible factors contributing to the casualty were listed according to the scheme of the AcciMap. And the relationship among the different departments was clarified. The seminar lasted two and half hours and an AcciMap of the Eastern Star incident was draft based on the investigation report.

To identify the actors involved in the Eastern Star incident more exactly, and based on the results of the first workshop, a second workshop was held on June 13 in WMU. A professor and a researcher from the MARISA Group and two students participated in the workshop. After confirmation from Chinese students with the investigation report, an ActorMap was drafted and the relationship of these actors was clarified. In addition, a micro ActorMap of the shipping company was created at the same time.

4.2An ActorMap of Eastern Star

After the preparation work, an ActorMap will be constructed first. The ActorMap is a graph identifying the various organizational bodies contributing to the landscape in which accidents flow and defining the relationship among actors. Due to the complexity, this representation tends to be hierarchically, ordered in a number of levels:

- Government,
- Regulatory bodies & Associations,
- Regional & Local government,
- Company.

The organizations involved in an accident can be listed according to the levels, and relevant relationships will be clearly described in a graph. In this way, the ActorMap can help provide an understanding of the organizational context.

4.2.1Liable departments according to the investigation report

Table 6. Departments and people were punished for Eastern Star accident

Name of department	**Number of people to be punished**
Ship company	9
Yueyang (a city of Hunan Province) MSA	3
Wanzhou (a district of Chongqing City) Maritime division	4
Wushan (a district of Chongqing City) Maritime division	1
Chaotianmen (a district of Chongqing City) Maritime division	1
Chongqing (Provincial rank city) MSA	3
Changjiang MSA	4
Changjiang River Administration of Navigational Affairs	3
Wanzhou Navigational Affairs Administration	10
Wanzhou SASAC	3

Wanzhou Transport Committee	1
Wanzhou district government	3
Altogether	45

From the Table 6, Wanzhou Navigational Affairs Administration and the shipping company take the main liability. Local administrations take full liability according to the governmental system in China. However, the central government takes responsibility for surveillance.

4.2.2 Constructing an ActorMap of Eastern Star

For the case of the Eastern Star, according to the investigation report, actors can be identified as in the map shown in Figure 10.

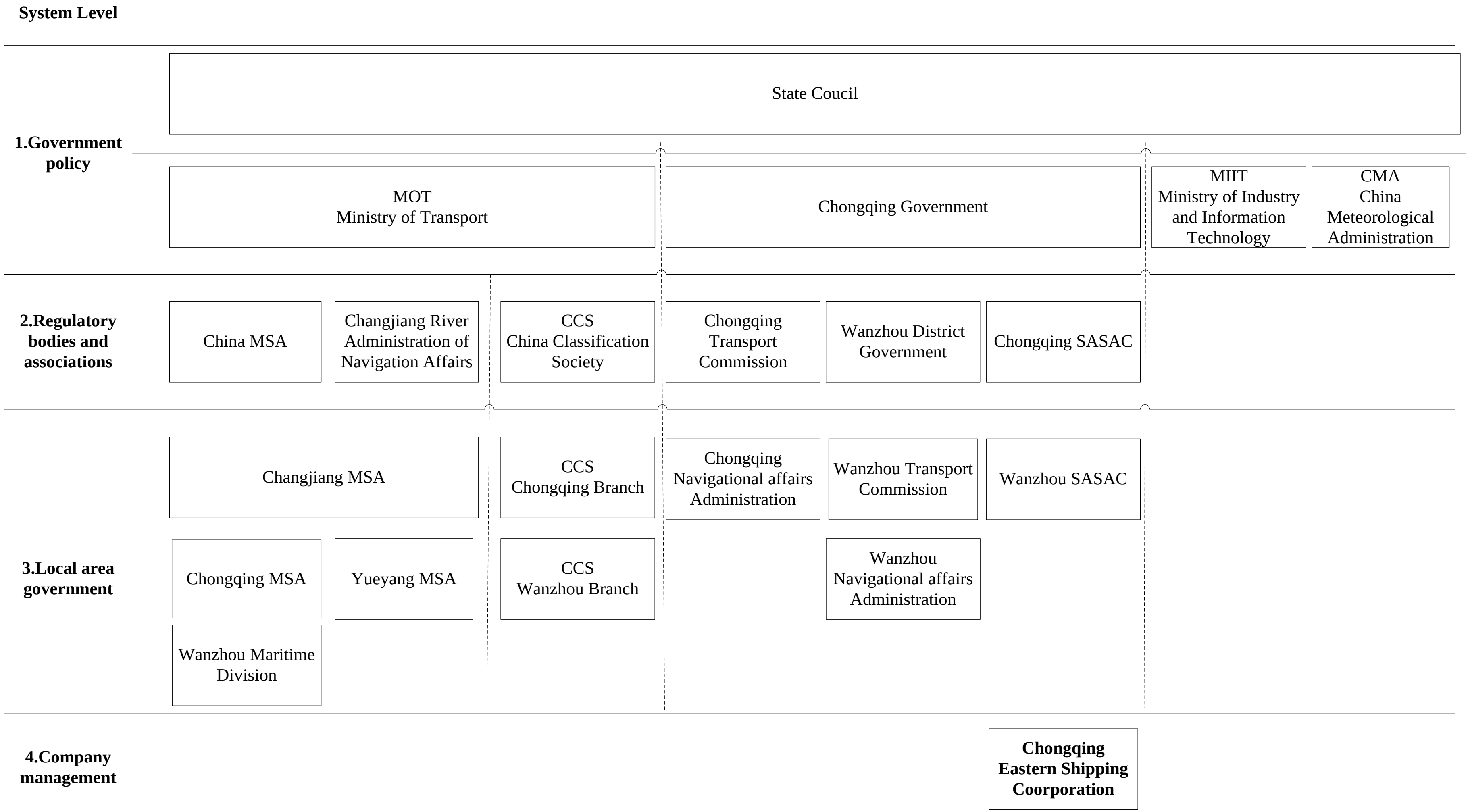

Figure 10. ActorMap of Eastern Star casualty

4.2.3 Identify Actors and their responsibilities in Eastern Star

According to the above map and table, both central and local governments as well as some organizations are involved in the accident. The departments are introduced as follows and some important departments' responsibilities are listed in Tables 7-10.

At the government level, the Ministry of Transport (MOT), the Ministry of Industry and Information Technology (MIIT) and China Meteorological Administration (CMA) under the State Council were involved in the accident according to the investigation report. Apart from the above organizations listed in the tables, China Meteorological Administration (CMA) is responsible for providing the weather forecast information and the Ministry of Industry and Information Technology (MIIT) is in charge of the standards of ship design and construction related to the Eastern Star.

At the Regulatory bodies & Associations level, China Classification Society (CCS), China Maritime Safety Administration (MSA), Chongqing municipal government and Changjiang River Administration of Navigational Affairs were involved in the accident.

At the Regional & Local government level, Changjiang MSA, Chongqing Transport Commission and SASAC (State-owned Assets Supervision and Administration Commission) of Wanzhou District, Chongqing were involved in the accident.

Changjiang MSA is in charge of the MSA Branch, VTS and SAR. Chongqing Transport Commission is in charge of local Navigational Affairs Administration, including shipping administration and ship inspection. SASAC of Wanzhou District is in charge of the Chongqing Eastern Shipping Corporation.

Table 7. The Ministry of Transport

Name of organization	Ministry of Transport (MOT)
Location	No.11 Jianguomennei Avenue, Beijing, China
Main duties	As a component department of the State Council, MOT, reconstructed in 2008, is responsible for railways, roads , highways ,shipping , ports , urban passenger transport, civil aviation and so on.
Institutional settings	17 internal organs (General Office, Comprehensive planning Department, Water Board, SAR Centre…); 2 agencies (Yangtze River Shipping Authority and Zhujiang Authority); 7 institutions (China MSA, CCS, Rescue and Salvage Bureau, DMU…) directly under MOT

Table 8. China Maritime Safety Administration

Name of organization	China Maritime Safety Administration (China MSA) Also called Maritime Bureau of MOT in China
Location	No.11 Jianguomennei Avenue& No.18 Anhuaxili, Beijing, China
Main responsibilities	Responsible for the exercise of national water safety supervision and the prevention of pollution from ships, vessels and marine facilities, maritime security management and administrative law enforcement, crew administration, fulfilling maritime safety management functions of MOT; also responsible for investigating the shipwreck.
Institutional settings	20 internal divisions (Navigation management, ship inspection management, crew management, security management service, maritime security administration, tube

	fouling at risk…); 14 branches under China MSA (Heilongjiang MSA, Changjiang MSA…); 27 provinces, autonomous regions and municipalities (excluding Heilongjiang Province, Guangdong Province, Guangxi Zhuang Autonomous Region, Hainan Province) and Xinjiang Production and Construction Corps have local maritime bureaus. Local maritime bureaus can be classified into provincial, municipal and county levels belonging to local governments. China MSA only gives them some technological direction.

Table 9. Changjiang River Administration of Navigational Affairs

Name of organization	Changjiang River Administration of Navigational Affairs of MOT (Also translated as Yangtze River Shipping Authority and abbreviated as “Changjiang Shipping”)
Location	Wuhan, China
Main duties	Authorized by MOT to take the administrative responsibility for the Yangtze River (Yunnan water Fu - Shanghai Yangtze River estuary, trunk waterways 2838 km). In detail as follows: 1.The drafting of the Yangtze River shipping regulations 2.Organize the preparation of the Yangtze River shipping plan and supervise its implementation 3.Yangtze River shipping, port and shipping facilities administration and industrial management 4.Quality of passenger and freight transport on the Yangtze River, port and shipping facilities engineering quality supervision and management

	5.Yangtze River water safety oversight and shipping Police Work 6.Coordination of 13 provinces related with Yangtze River
Institutional settings	11 internal divisions (Transport management, safety administration, waterway and navigation administration…); 8 institutions (Changjiang MSA, Changjiang Waterway Bureau, Changjiang Three Gorges Navigation Authority…) directly under Changjiang Shipping

Table 10. China Classification Society

Name of organization	China Classification Society (CCS)
Location	Headquarters located in Beijing, China
Number of Staff	CCS has about 4,100 employees and has established over 80 offices both at home and abroad, forming a global service network.
Main responsibilities	Founded in 1956, China Classification Society (CCS) is the specialized organization in China that provides classification services. CCS aims to provide services for shipping, shipbuilding, offshore exploration and related manufacturing industries and marine insurance by furnishing reliable classification requirements and providing independent, impartial and integral classification and statutory services to ships and offshore installations, for the promotion and safeguarding of the safety of life and property at sea and for the prevention of pollution to the marine environment.

4.2.4 Shipping Company

At the company level, Chongqing Eastern Shipping Corporation takes direct responsibility for the incident. In detail, the Technical & SMS Department, HR, the Transport Department and the company-owned shipyard took the liability for the incident. (See Figure 11)

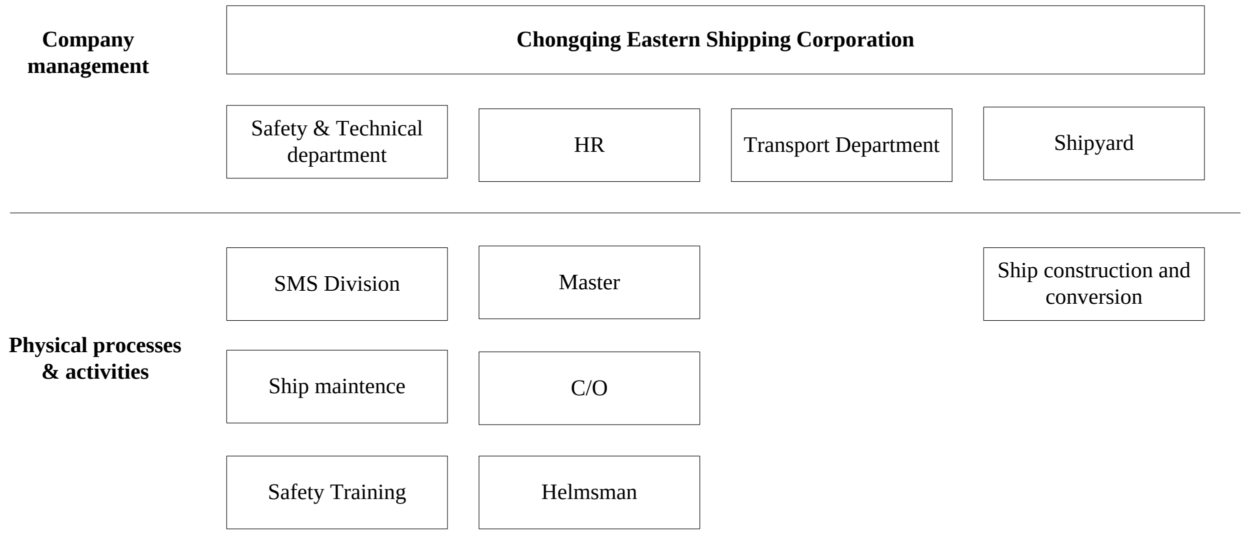

Figure 11. ActorMap of Chongqing Eastern Shipping Corporation

In detail, from the information listed above, some important questions during the ship construction and safety management can be identified as follows:

(1) The Ministry of Industry and Information Technology (MIIT) is responsible for the general principles and rules for construction of domestic ships.

(2) Chongqing Navigational Affairs Administration and its Wanzhou branch (including ship survey bureau) are in charge of the granting permit, supervision and survey of ship construction.

(3) The ship design institutes would check the ship's technical information and the Chongqing Navigational Affairs Administration and its Wanzhou branch (including ship survey bureau) would double check and approve the ship construction plans. Then, the shipyard of Chongqing Eastern Shipping Corporation is in charge of the several conversions of the Eastern star.

(4) Generally, CCS and its local branches check the stability of ship. Wanzhou Navigational Affairs Administration inspected the stability of the Eastern Star.
(5) Changjiang River Administration of Navigation Affairs is in charge of issuing water transport permits to the Chongqing Eastern Shipping Corporation.
(6) Changjiang MSA, Chongqing MSA and Wanzhou MSA should be responsible for issuing the safety management system from the ISM code to the Chongqing Eastern Shipping Corporation and monitoring the safety performance of ships through periodical inspection. Besides, Changjiang MSA should also be responsible for supervising and monitoring ship navigational safety in the Changjiang River by VTS and other related methods.
(7) Wanzhou State−owned Assets Supervision and Administration (Wanzhou SAASC) is directly in charge of the Chongqing Eastern Shipping Corporation and supervises the safety performance of the shipping company.

4.2.5 Summary

In China, MOT takes overall responsibility for water transport and China MSA takes responsibility for maritime safety administration on behalf of MOT. Considering the importance of the Yangtze River, authorized by MOT, Changjiang Shipping takes administrative responsibility for the Yangtze River covered trunk waterways of 2838 km and coordinates relevant affairs of 13 provinces. CCS, an institution of MOT, provides services for shipping, shipbuilding, offshore exploration and related manufacturing industries and marine insurance, including drafting the standards for shipping inspection.

At the regional level, the local MSA belongs to its territorial government and receives technological direction from MOT’s representative as China MSA and Changjiang Shipping.

In the Eastern Star case, two component departments of the State Council were involved in the weather forecasting responsibility of the CMA and standards of ship design and construction responsibility of the MIIT.

At the company level, Chongqing Eastern Shipping Corporation belongs to Wanzhou SASAC; therefore, SASAC of Wanzhou should be responsible for administrative lapses related to the accident.

4.3An AcciMap of Eastern Star

4.3.1 Drawing an AcciMap

The AcciMap (Rasmussen 1997; Svedung and Rasmussen 2002) is an accident analysis method that is used to graphically represent the system-wide causal failures involved in accidents, as well as identifying the environmental conditions and physical processes involved. It also focuses on the causal flow of events upstream from the accident, looking at the planning, management and regulatory bodies that may have contributed in some way (Svedung and Rasmussen 2002). Typically, the following six levels of complex socio-technical systems are considered (although these can be modified to suit analysis needs): topography and configuration of scenery and equipment, accidental flow of events and acts, technical and operational management involved, company management and local area planning, regulatory bodies and associations and government policy and legislation.

Combining the information above with the investigation report, an AcciMap of Eastern Star can be drafted as in Figure 12:

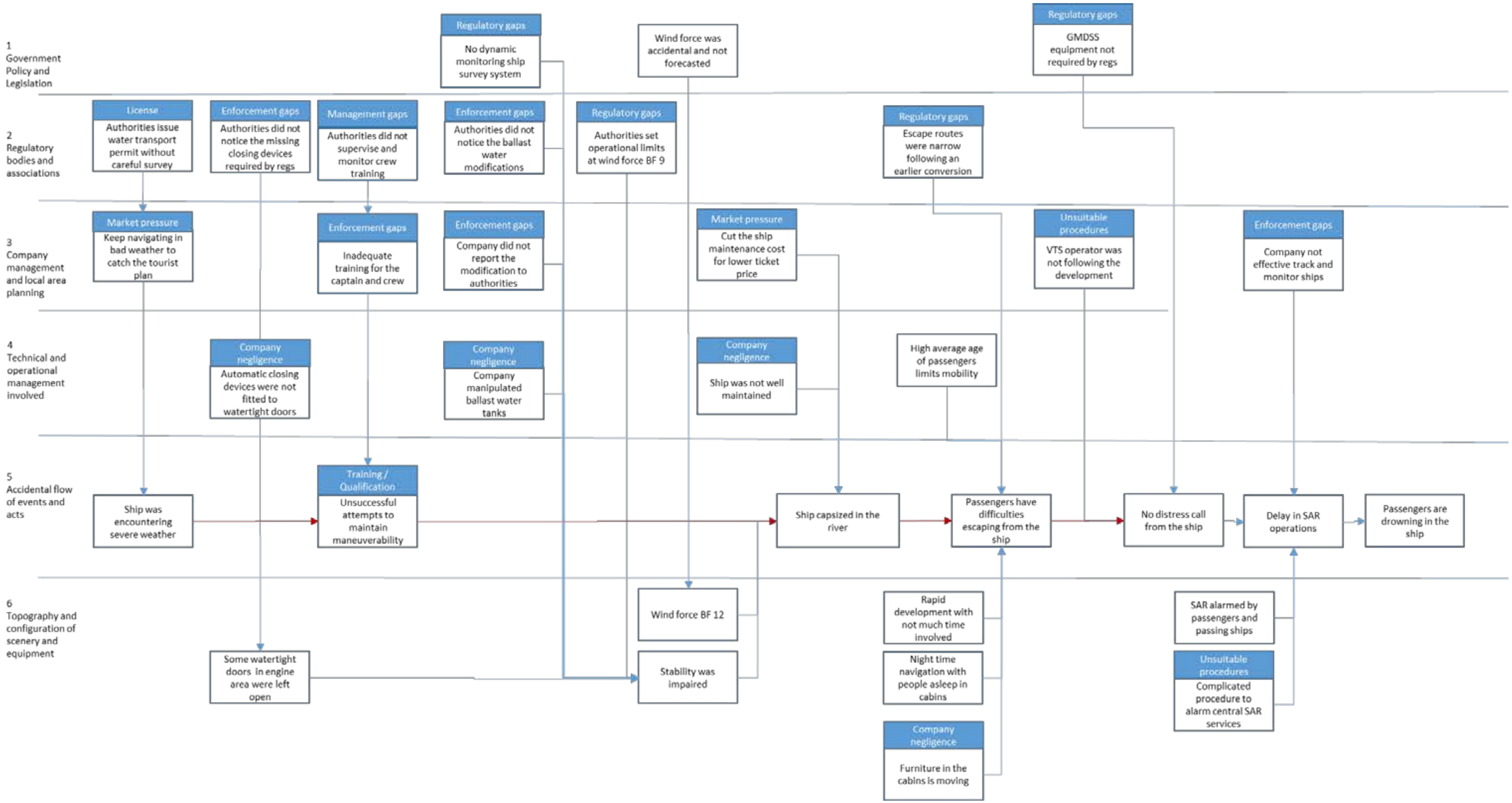

Figure 12. AcciMap of the Eastern Star casualty

4.3.2 Explanations

Accidental flow of events and acts First, the accident flow of Eastern Star can be outlined with a series of events and acts as level 5 with red arrows. The ship encountered severe weather, which led to an unsuccessful attempt to maintain maneuverability. It capsized into the river immediately and passengers on board had difficulty escaping from the ship. No distress call was sent out. The tragedy caused a total of 442 deaths with only 12 persons surviving.

Topography and configuration of scenery and equipment At the time of the accident, a squall line system appeared above the waters where the Eastern Star navigated, accompanied with downburst, tornadoes, and other short-term local heavy rainfall, as well as severe convective weather. Waters where the ferry capsized suffered strong storms with the maximum wind speed reaching 32-38m/s (Bf 12-13). The unanticipated tornadoes directly caused the capsizing.

The extreme weather conditions encountered by the Eastern Star resulted in the loss of stability. After the initial construction of the ship, it underwent rehabilitation and technical changes on three occasions and the fundamental stability criterion numeral of wind pressure was gradually reduced (see Table 11). Although it is still in line with regulatory requirements, the ship will capsize when encountering 21.5 m/s beam wind (BF 9) or 32.0 m/s maximum instantaneous wind speed (BF 11) with 21.1°~156.6° wind angle according to calculation and experience. The navigational area for the Eastern Star is approved as level B, which means it will lose stability when subjected to 21.52 m / s (Bf 9). However, at the time of the accident, the wind reached Bf 12.

Table 11. Changes of the stability criterion[1]

Years	1994	1997	2008	2015
Ship stability (weather) criteria (K)	1.355	1.09	1.018	1.014

Some equipment on the Eastern Star was also problematic. The watertight doors in the engine area were left open and beds in the cabins were not well fixed. Additionally, the accident happened at night when most people were asleep in their cabins and the rapid development with capsizing made the time for escaping extremely limited.

The captain and crew did not send out any SAR alarm. It was the rescued passengers and a passing ship that alerted the SAR authorities. It also took a long time to report to central SAR services due to the complicated procedures.

Technical and operational management involved At the technical and operational level, the company manipulated ballast water tanks during the conversion in 2015 and did not report the change to authorities. This conversion impaired the stability of the ship. Automatic closing devices were not fitted to watertight doors and were not noticed during daily checks. The ship was not well maintained and potential risks were not controlled in advance.

The passengers were organized by a small travel agency in Shanghai named after “Red Sunset Group” that was designed for retirees and offered a discounted price in non-peak time. Most of the passengers were over 60 years old. The accident happened at about 21:30 when most of the passengers were asleep in their cabins due to their habits and the heavy shower. The limitation of their mobility and the short response time made it impossible to escape. Most of the passengers were not aware of what was happening outside when they lost their lives by drowning with the capsizing of the ship.

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[1] The stability criterion, which usually is expressed by the letter K, is one of the important and basic requirements for ship stability. It is stipulated that the stability of the ship under the various loading conditions calculated shall be in accordance with the following inequality formula of K>1.
K =lhmin/lw, lhmin means the minimum heeling lever, lw means the wind heeling lever

Company management and local area planning At the company management level, Chongqing Eastern Shipping Corporation took direct responsibility for the accident. The problematic management regime and implementation of regulations in Chongqing Eastern Shipping Corporation was exposed following this accident. Some ships with similar routes changed their schedules according to the weather forecast and avoided the dangers. However, the Eastern Star was already delayed according to the tourist plan in the first two days and was told to regain lost time to maintain the original schedule, so it continued navigation under the dangerous weather conditions.

The company adjusted the ballast tanks without applying inspections from local professional institutions. The captain and senior officers on board had not received adequate training, especially for response to extreme weather conditions. When the accident happened, the captain did not recognize the potential risks caused by the severe weather. He did not send out a distress message or sound an alarm to the whole ship. The captain and crew did not organize any kind of evacuation from the ship. The newly hired crew members were not qualified for their positions due to inadequate training and careless assessment. The daily security checks were not thorough enough to identify problems such as lack of closing appliances to prevent water ingress and unfixed beds in cabins. In addition, there were no full-time staffs in charge of ship daily maintenance. The monitoring systems were not under dynamic tracking and the VTS operators were not following the development.

Regulatory bodies and associations At the Regulatory bodies & Associations level, Changjiang River Administration of Navigational Affairs had not effectively implemented the shipping administrative department duties and issued waterway transport licenses without careful survey. Changjiang MSA did not audit the safety management system of the company strictly and failed to identify regulatory loopholes. The crew training was not supervised effectively. The problematic modifications, including ballast water tank adjustments and narrowing of escape routes, were not noticed. The lack of closing devices required by regulations was not detected during inspections. Yueyang MSA did not implement the requirements from MOT and Changjiang MSA to maintain tracking and monitoring of every passenger ship navigating in Changjiang. The operational limits at wind force BF 9 were not safe enough considering the poor condition of some old ships.

The surveillance system of relevant local administrations did not play a full role in safety management on ships. Local ship inspection departments like Chongqing Navigational Affairs Administration (Chongqing Inspection Bureau is included) and Wanzhou District Navigational Affairs Administration (Wanzhou Ship Inspection Bureau is included) did not make a serious inspection on Eastern Star after it was reconstructed and did not find the problems of its illegal adjustment of ballast tanks and poor equipment in cabins. The certificates were issued without serious surveys and inspections. The crew training and assessment was not under effective supervision. The higher levels of administration like the Chongqing Transport Commission also did not conduct an effective surveillance for all of these potential safety risks.

As the lead department of Chongqing Eastern Shipping Corporation, Wanzhou District SASAC did not carry out strict safety supervision and inspection of the company and did not find the fraud in training and assessment or the unhealthy management regime of the company.

Government Policy and Legislation The wind force was unforeseen and not forecasted by meteorological departments due to their current technological capabilities. No dynamic ship survey system was available to authorities to monitor the conversions of ships. Necessary equipment under IMO regime, such as GMDSS, was not mandatory on domestic ships in China.

As central government bodies, the Ministry of Transport (MOT) and the Ministry of Industry and Information Technology (MIIT) have the responsibility to set relevant policies, standards and regulations but they are not empowered to punish the entities for their faults. Sometimes they can advocate and require the local departments and companies to follow the safety regulations by issuing provisions. But they cannot control the actual results.

4.3.3 Summary

The analysis found a number of key failures, all of which contributed to the Eastern Star Casualty. These failures were related to the equipment, the characteristics of the passengers, loopholes in the management regime of the company and the defective surveillance from all levels of administration. These causes have been analyzed with the framework of the AcciMap at the six levels and have also been catalogued into several aspects that relate to recommendations in the following chapters.

4.4An ActorMap of Sewol

4.4.1Constructing an ActorMap of Sewol

According to the investigation report into the Sewol accident, an ActorMap is drafted as shown in Figure 13.

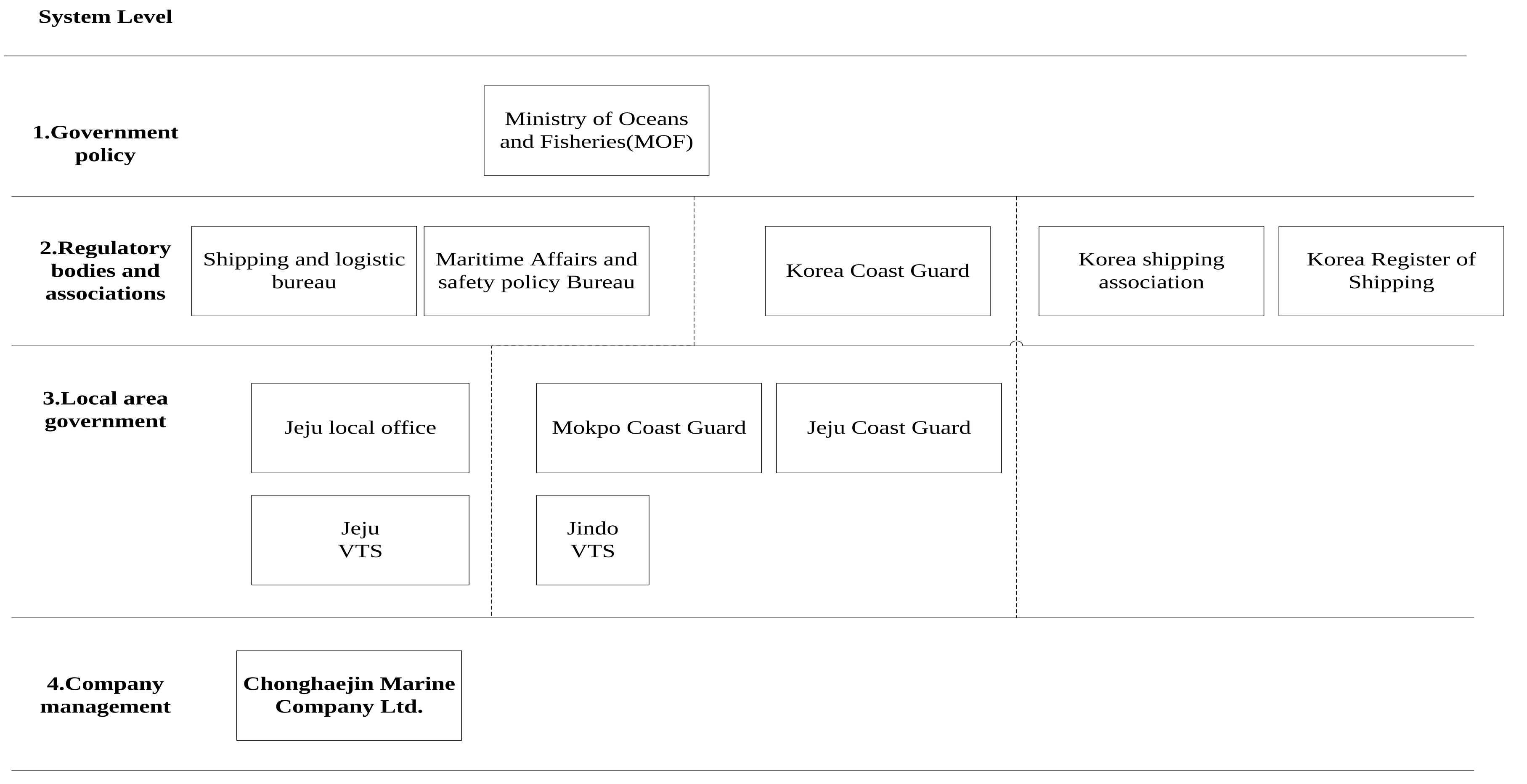

Figure 13 ActorMap of the Sewol casualty

4.4.2 Identify Actors and their responsibilities in Sewol

At the government policy level, the Ministry of Oceans and Fisheries (MOF) takes full responsibility for maritime safety in the Republic of Korea.

At the time of the Sewol accident, three departments, the Shipping and Logistic Bureau, the Maritime Affairs and Safety Policy Bureau and Korean Coastguard, were under MOF and carried out some administrative responsibilities on behalf of MOF, according to national laws and regulations. They are at the regulatory bodies and associations level. Besides these three departments, Korea Shipping Association and Korea Register of Shipping acted as technical associations and conducted surveys and related technical tasks authorized by MOF.

At the local area government level, Jeju local office, Mokpo Coast Guard and Jeju Coast Guard were in charge of local maritime safety and the local VTS of Jeju and Jindo.

At the company management level, Sewol belonged to Chonghaejin Marine Company Ltd., major shareholders of which are Haiti (39.4%), Kim Han-sik (11.6%), and I.ONE.I (7.1%). The company was actually controlled by Yoo Byung-Eun who was the president of SaeMo Group.

4.4.3 Summary

As the highest authority, MOF takes responsibility for defining the national maritime safety system for domestic passenger ships in the form of policies and regulations. Under its leadership, the Shipping and Logistic Bureau, the Maritime Affairs and Safety Policy Bureau and the Korean Coastguard have operational responsibility and supervise associations like the Shipping Association and Korea Register of Shipping on behalf of MOF. There are some branches and sub-branches carrying out similar responsibilities in the local domain.

4.5An AcciMap of Sewol

4.5.1Drawing an AcciMap

Similar to the Eastern Star, after actors were identified, the Sewol AcciMap can be draw as shown in Figure 14 with cause identification and analysis.

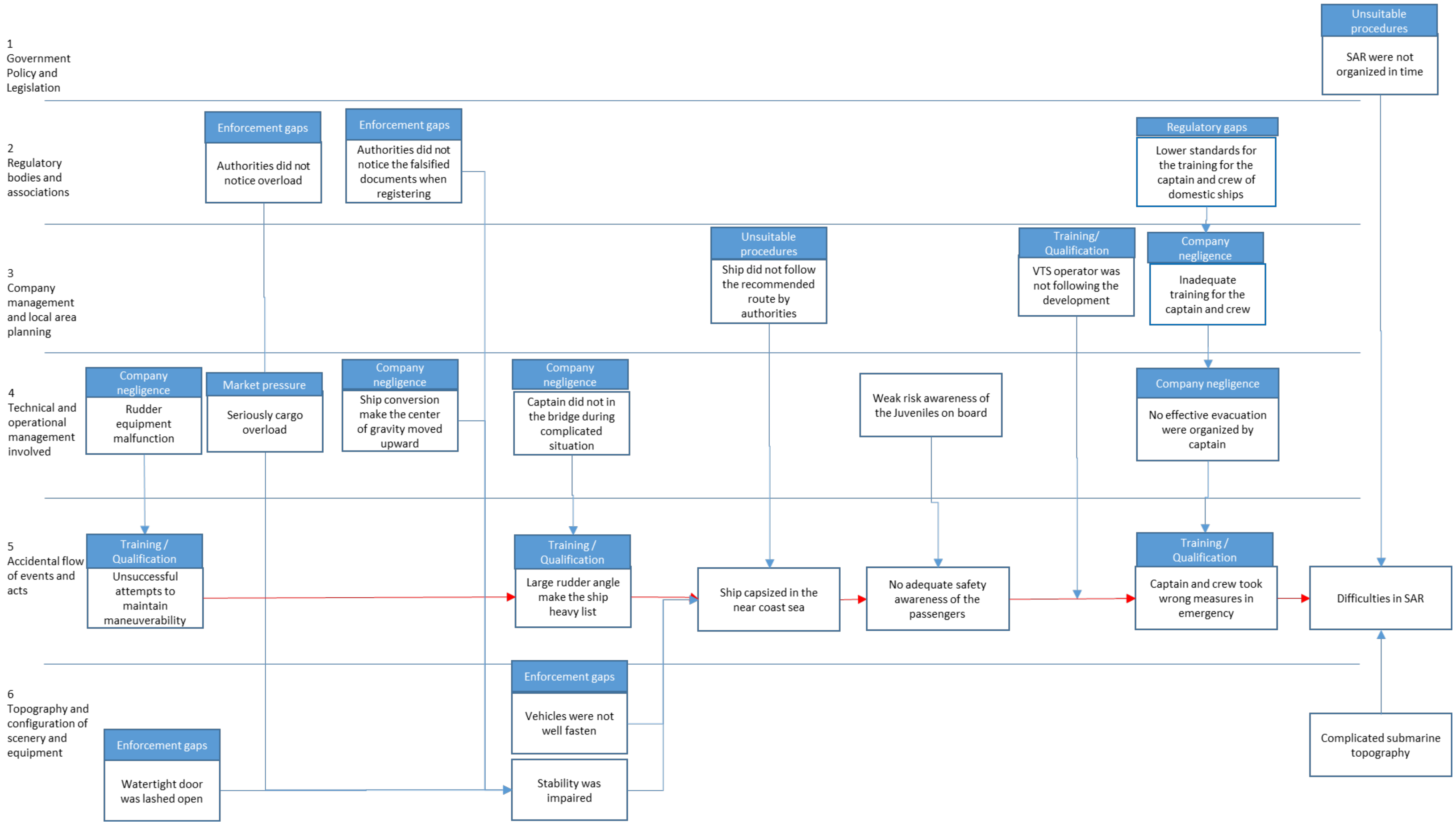

Figure 14 AcciMap of the Sewol casualty

4.5.2 Explanations

Accidental flow of events and acts Firstly, the Accident flow of Sewol can be concluded in a series of events as shown by the line with red arrows. The accident occurred at 20km north of Screen Island, Ronan County, where the natural conditions are complicated. The inexperienced helmsman felt the rudder angle was significantly larger than normal steering and was unsuccessful in the attempt to maintain maneuverability. The large rudder angle made the ship list heavily and the ship capsized in the near coastal sea. The inadequate awareness of risk of the passengers, the improper actions of the captain and the delay in SAR increased the loss of lives to 304 in the end.

Topography and configuration of scenery and equipment The submarine topography where the accident occurred is rather complicated with a number of underwater obstructions. It is difficult for the ship to navigate under the influence of wind, stream, wave, surge, and fog. The complex environment also brought out problems for rescue. The waters where the accident occurred were about 30-meter deep with a 0.5 m wave height and 11.7 degrees Celsius water temperature. The visibility was only 20 cm for SAR and the flow rate reached 8 km / h.

The crew did not close the watertight doors according to the regulations. The ship listed dangerously in one direction, resulting in flooding in watertight compartments. Flooding could have been avoided if internal watertight devices had been in place. The staff’s negligence sped up the capsizing.

Vehicles on board were not well fastened. When different kinds of vehicles were loaded, they should have been fastened to prevent displacement during transportation. When the accident occurred, 180 cars, 22 trucks and 34 sets of trucks over 2.5t were not effectively fastened with a chain or rope, resulting in heavy movement.

Technical and operational management involved A malfunction in the rudder equipment was identified in the investigation report. The materials for rudder maintenance applied by Sewol were aging due to their long existence. The problematic rudder device caused a significant error when steering. The ship continued rotating until the rudder reached the maximum steering angle so that the ship was out of control. When navigating in the complicated waters, the young helmsman operated the ship improperly with a sharp turn from 135 to 150 degrees. The Sewol began to list to port and tilted towards the water while the captain was not on the bridge. The overall effect was that the ship turned about 45 degrees to the right and rotated 22 degrees on the spot for a span of 20 seconds. The cargo fell to one side of the ship causing the Sewol to lose all of its restoring force and allowing water to flow into the ship through the side door of the cargo-loading bay and the car entrance located at the stern.

Excessive and problematic modifications were made to the Sewol. At the time of its purchase by Chonghaejin Marine on 2012, the ship that would come to be known as the Motor Vessel (MV) Sewol was 18 years old and dilapidated. It was first named Ferry Naminoue and was operated from 1994 to 2012 as a transport ship for cargo and passengers by the Japanese company A-Line Ferry. After it was purchased on 8 October 2012, the vessel was registered by Chonghaejin on 22 October 2012 and underwent modifications from 12 October 2012 to February 12, 2013. The modifications were based on an illegal redesign of the ship. After the modifications, which included the addition of extra passenger cabins on the third, fourth, and fifth decks, Sewol's passenger capacity was increased from 804 to 956, including the crew, 180 vehicles, and 154 regular cargo containers. The vessel weighed a total of 6,825 tons, and had 46 rubber lifeboats, each with a capacity of 45. It could travel at a maximum of 22 knots (41km/h; 25mph) and its weight was increased by 187 tons. The modifications resulted in the ship’s center of gravity being moved upward by 0.51m (1ft. 8in) as well as a left-right imbalance.

The ship was seriously overloaded. According to the documents quoted by the Associated Press, during the total 394 voyages between Incheon and Jeju after modifications, the overloading times reached as many as 246 and among them there were 136 times of loading cargo over 2,000t and 13 times of more than 3,000t. On April 16, when the accident occurred, Sewol carried more than 400 passengers, 180 cars, 22 trucks and 34 sets of trucks over 2.5t, with a total weight of 3,608t, which was 3.66 times the full load. This was almost the worst overloading on record. It was easy to capsize in such an overloaded condition, especially when encountering bad weather like wind, rain, snow, or fog.

Interestingly, the Sewol was equipped with enough advanced escaping facilities, but only two among 44 lifeboats were opened and 4 escape ships, which can accommodate over a thousand of persons, were not opened at all in the accident. When in a state of emergency, the captain did not make an effective response. Since the captain misjudged the dangerous situation and lack of capability to deal with emergencies, he failed to organize the crew to take timely measures to help the passengers, including guiding the passengers to evacuate immediately to the place where the lifeboats and life rafts were placed. Even when Jindo control center told the captain to direct the passengers to wear lifejackets as soon as possible for emergency evacuation and escape, the crew did not completely fulfill the corresponding duties. It is the captain and crew's weak risk knowledge and skills that resulted in missing the best time for escaping.

Company management and local area planning The Sewol did not follow the course suggested by MOF and navigated a course with many shoals, reefs, islands and other obstacles. Stranding, grounding and other accidents often occurred in those areas. The accident happened in an area with many obstacles and the helmsman had planned to escape from the dense obstacles and steered sharply, which resulted in the accident.

Main passengers on the Sewol were juveniles who had lack of sense of crisis and were not trained to cope with the dangerous situation on board. Video records illustrated that some students kept playing even when the broadcast required them to don lifejackets. Since it was time for breakfast, many passengers were trapped in the downstairs shops, restaurants and entertainment venues, which were difficult to escape. When sinking into the water, they could only survive a short time due to the cold water and scarce air.

Jindo Traffic Control Centre (VTS) staff did not follow the provisions to maintain monitoring, made false exchange records and attempted to delete the electronic surveillance files when investigated by prosecutors.

The Captain and crew did not take responsibility in the emergency. The inexperienced helmsman was incapable of controlling the ship by herself especially in a complicated situation while the captain left her alone. The captain even abandoned the ship, leaving most of the passengers still in danger. Neither the captain nor crew received adequate training especially in the knowledge and capability to cope with emergency situations.

Regulatory bodies and associations From October 2012 to February 2013, the Sewol was subjected to a 5-month testing period by the South Korean Register of Shipping, after which the Register approved the modifications made. However, the Register decreased the authorized cargo capacity by half to 987 tons and required 2,000 tons of water to serve as ballast in order to provide balance. The upward stability was not seen as a potential risk when the Sewol was registered.

The Government's Audit and Inspection Board later revealed that the Register's licensing was based on falsified documents. Prosecutors later estimated that 1,077 tons of cargo was permissible and that 1,695 tons of ballast was necessary to carry 1,077 tons of cargo. The overload problem was very serious in the SEWOL and happened quite frequently in past voyages. However, it failed to draw enough attention and was not punished by relevant organizations.

STCW regulates that the duties on a ship arranged by captains should be suitable for safe navigation. Obviously, the captain of the Sewol did not make a reasonable duty arrangement. In addition, the captain should help everyone on board to escape and is bound to be the last person to leave the ship in distress, according to international practice. In this case, the captain was among the first group of people rescued, while most passengers were still in the capsizing ship. Compared with international conventions, the requirements and training for captains and crew of domestic ships are neither mandatory nor adequate.

Government Policy and Legislation After the incident, the Korean navy, fire department, police, and coastguard dispatched a total of 16 helicopters and 24 ships to carry out the emergency rescue, and offshore fishing vessels in the vicinity also were involved in the rescue work. The Ministry of Oceans and Fisheries of the Republic of Korea even collected volunteers from around the country who could dive to join the SAR task. American Richard amphibious assault ship (USS Bonhomme Richard (LHD 6)) and synergistic ship-borne helicopters were involved in the rescue. However, SAR process did not have a successful result for the reasons of delayed emergency response, confused disaster information report, poor coordination with the victims and inadequate scientific and technological support.

4.5.3 Summary

The failures identified and analyzed in the Sewol accident, with the help of AcciMap, include complicated navigation environment factors, responsibilities of captain and crew, the profit-oriented shipping company without basic safety concerns and inadequate governance. Similar to the Eastern Star accident, AcciMap is also helpful in providing recommendations that will be discussed in the following chapters.

5 Comparison of the two accidents

Coincidently, the two Asian accidents, Eastern Star and Sewol, have some major points in common. Both ships involved in the accidents were initially built in 1994 and were retrofitted several times. IMO conventions were not applicable to these ships since both were involved in domestic shipping. These accidents resulted in considerable loss of lives and had similar safety management issues. A comparison of the accidents will assist in carrying out safety assessment of the risks in domestic shipping in China and the Republic of Korea. Risk mitigation options may allow application of IMO conventions in the national domain for amelioration of safe and environmentally friendly shipping. Respective administrations should pay more attention to these comparisons to avoid repetition of such accidents.

Combined with the above content of this study, a comparison will be made at two levels of factual information and identified failures by AcciMap.

5.1Comparison of factual information

Table 12. Factual information comparison between Eastern Star and Sewol

Information	Eastern Star	Sewol
Ship type	Cruise ship	Ro-Ro passenger/cargo ship
Capacity	534 passengers and 50 crew	921 passengers, 35 crew, 180 vehicles and 154 regular cargo containers
Built and modifications	Initial build in 1994 and retrofitted in 1997, 2008 and 2015	Initial build in 1994 and retrofitted in 2013
Persons/cargos on board during accident	398 passengers and 46 crew	446 passenger and 30 crew, 185 vehicles, 150 containers and 1157 tons of cargo
Ship company	Chongqing Eastern Shipping Corporation, invested and administrated by Wanzhou District SASAC of Chongqing	Sewol belonged to Chonghaejin Marine company; major shareholders were Haiti (39.4%), Kim Han-sik (11.6%), I.ONE.I (7.1%). It was actually controlled by Yoo Byung-Eun, President of SaeMo Group.
Accident area	Yangtze River of China	Donggeochado of the Republic of Korea

Accident time	At 21:30 on June 1, 2015	On the morning of 16 April, 2014
Passengers on board	Most of the passengers were over 60 years old from a tourist group named Red Sunset.	Main passengers in Sewol were students from Danwon High School.
Sinking time	The accident occurred due to inclement weather and lead to capsizing followed by sinking in 2 minutes.	The ship sank after more than 3 hours post capsizing.

5.2Comparison of identified failures

Table 13. Identified failures comparison between Eastern Star and Sewol

Identified failures	Eastern Star	Sewol
Accidental flow of events and acts	The ship encountered severe weather, causing unsuccessful attempt to maintain maneuverability. It capsized into the river immediately and passengers on board had difficulty to escaping from the ship and no distress message was passed.	The inexperienced helmsman observed that the rudder angle was significantly larger than normal steering, which led to a loss of maneuverability. Excessive list was resultant from the large rudder angle, causing the ship to capsize in coastal sea.
Topography and	At the time of accident, a squall line system appeared	The accident occurred in a narrow channel with torrential

configuration of scenery	above the waters where Eastern Star navigated, accompanied with downburst, tornadoes and other short-term local heavy rainfall coupled with severe convective weather. Waters where the ferry capsized suffered strong storms with the wind speed-reaching maximum to 32-38m/s (Bf 12-13).	water but not at its peak time.
Equipment	The watertight doors in engine area were left open and beds in cabin were secured seaman like.	The watertight doors were left open. Vehicles on board were not well fastened.
Technical and operational management	The company manipulated ballast water tanks during the conversion in 2015 and did not report to authorities. This conversion impaired the stability of the ship. Automatic closing devices were not fitted to watertight doors and were not noticed during the daily checks. The ship was not well maintained and potential risks were not controlled ahead.	The rudder equipment malfunction was discovered in the investigation report. The excessive and problematic modifications resulted in its centre of gravity being shifted upward by 0.51m (1ft. 8in) as well as a left-right imbalance. The ship was seriously overloaded. Effective response was missing from Captain during the emergency. Escape routes were adequate and different facilities for

		escape existed, but were not used capably.
Company management	The Eastern Star was directed to compensate for the time lost previously by keeping the original schedule leading to continuation of navigating in dangerous weather conditions. The company manipulated the ballast tanks without inspections from local professional institutions. The captain and senior officers onboard were not trained adequately especially for the response to extreme weather conditions.	Sewol did not follow the course as suggested by MOF and navigated close to many shoals, reefs, islands and other dangers around. The inexperienced helmsman was incapable to control the ship by herself especially in a complicated situation in the absence of captain. The captain and other crewmembers abandoned the ship leaving most of passengers to their fate.
Local area planning	Most of the passengers were over 60 years old and the accident happened at their sleeping time. The limitation of their mobility and the short response time made it impossible to escape. The monitoring systems were not under dynamic tracking and the VTS operators were not following the development.	Main passengers in Sewol were juveniles lacking sense of crisis and were not trained to cope up with dangerous situations onboard. Jindo Traffic Control Centre (VTS) staff failed to monitor continuously followed by falsifying records and tried to deleting electronic surveillance files while prosecution was in progress.

Regulatory bodies and associations	The authorities issued the waterway transport licenses without careful survey. The safety management system of the company and crew training were not supervised effectively. The problematic modifications were not noticed. The missing closing devices required by regulations were not found out during inspections. The surveillance system of relevant local administrations did not play a full role in safety management on ships.	The Republic of Korea government's Audit and Inspection Board later revealed that the Register's licensing was based on falsified documents. The upward stability was not looked as a potential risk when the Sewol was registered. The overload problem was very serious in SEWOL and it happened quite a number of occasions in the past voyages but went unnoticed and therefore was not punished by relevant organizations.
Government policy and legislation	The wind force was accidental and not forecasted by meteorological departments due to the current technological capabilities. No dynamic ship survey system was existed to monitor the modifications carried out for the ships by any of the authorities. Necessary equipment like GMDSS under IMO regime was not mandatory on domestic ships in China.	The process of SAR was not a successful one from the result for the reasons of lag emergency response, confused disaster information report, poor coordination with the victims and inadequate scientific and technology support.

5.3Summary

Similarities and differences can easily be concluded from the above tables. As far as the factual information is concerned, both accidents caused a huge loss of life, while the time and weather conditions were quite different, leading to the great difference in number of survivors. The weather conditions that the Eastern Star encountered were extremely severe and peculiar, and the Sewol was reported to start sailing in foggy conditions and suffered from the complicated topography. The natural situation directly caused or catalysed the accidents. However, the accidents could have been avoided if the companies had carried out the safety management regulations and stopped the navigations in time.

Similar enforcement, regulatory, management and training gaps can be found from the comparison. The modifications impaired the stabilities and the situation went unnoticed and uncorrected by authorities. Maintenance and daily safety checks were not adequate and some problematic equipment was not detected. Training programs such as contingency planning and emergency preparedness for captain and crew were inadequate. Generally, the regulations on the domestic ships both in China and the Republic of Korea were not as strict as that on ships under IMO regime.

In the Eastern Star case, the unsuitable procedures sometimes constrained the results of surveillance and disciplinary action to the problematic companies could not be taken in time.

In the Sewol case, there were some unsuitable procedures in SAR, which were not organized effectively and efficiently to enable a fast response in rescuing and saving more lives.

6 Discussions and findings

6.1Contributions of AcciMap

The analysis of the tragic capsizing of Eastern Star and Sewol was approached from the multi-layered diagrams by examining weaknesses in the safety control structure. The approach of AcciMap has served three main aims of the paper:

- Identification of the actors involved in the accidents and relationship among them for further deliberation of the failures.
- Illustrated questions according to the layers in AcciMap and uncovered the rationale behind the decisions made leading to such a high number of fatalities.
- Formulated safety recommendations by classifying the causes associated with different problems and developing relevant compensation in the future.

As Leveson (2011) pointed out, if the purpose of accident analyses is to find the ‘‘root cause” or someone to blame, we might lose the sight to seek potential opportunities to maximize what can be learned from the accident.

The Eastern Star accident happened in extreme weather conditions that led to the huge loss of life. Through post analysis using AcciMap, human factors can be identified clearly. The ship’s company undertook modifications without approval from the local inspection department and the lead department also failed to check the same. The training imparted to captain and crew was inadequate and they were, therefore, unable to cope up with the complicated situation while navigating in such harsh weather conditions. The safety equipment was not checked prior to sailing or during rounds.

The rudder command – regardless of whether it was a flawed human decision or a technical error, should not be addressed as a primary explanation for the Sewol accident. The financial incentives and cost-cutting efforts of ship-owners led the vessel to an alarming high-risk state, making it more vulnerable to accidents. Government regulatory agencies and industry associations failed to enforce proper constraints. Moreover, effective feedback channels to report safety critical information to authorities were not established. The activities carried out on board were not monitored in respect to correctness. Thus, the improperly designed vessel safety control structure with unbalanced responsibility created an unacceptably hazardous condition. Authorised personnel responsible for taking decisions regarding vessel conversion design, approval, cargo arrangement, crew management, vessel operation and inspection were either ignored or unaware of the negative impact of their decisions on other parts in the safety systems (Kim, Nazir, & Øvergård, 2016).

The AcciMap provided the logical levels for causal factors and connections analysis. It enables the compilation of large amounts of information regarding different causes of accidents, the area of the socio-technical system in which each factor arose and precisely how the factors came together to produce the accident, within a single coherent diagram. The approach promoted a systematic view of accident causation and focused on repairing system deficiencies to mitigate future accidents rather than reprimanding the individual involved and leaving the deficiencies that promoted their actions unaddressed. In addition, it assisted in safety recommendation development relating to the high levels regarding legislation, regulations, certification, auditing and government decisions.

6.2 Constraints and future improvements

Constraints were experienced in collecting evidence. Maximum information was retrieved from the investigation reports in local languages. Inappropriate understanding due to local language and translation may impair the accurate analysis. The causes identified from the investigation report could not be completed and well fitted in the AcciMap levels. Due to the complicated administrative procedures both in China and the Republic of Korea, the liabilities are not easy to be concluded at higher levels. The quality of the analysis produced by AcciMap entirely depends upon the quality of the input data used. Accurate and comprehensive data is not always available as much of the investigation may be based on assumptions, domain knowledge and expertise. The output does not explicitly generate remedial measures or countermeasures and these are based entirely on analyst judgment, leading to reduce the reliability.

For example, in the Sewol case, few components were indeed operated ‘reliably’ in terms of making decisions (e.g., KR) based on their context and information they possessed. However, poor coordination and communication, and dysfunctional interaction among the components of the total safety system played a critical role in leading to the dangers involved and escalation to an accident. Obviously, many of these systemic casual factors are only indirectly related to the immediate events and conditions (Kim, Nazir, & Øvergård, 2016).

It is very difficult to ease the burden of the affected people whose lives have been changed post accident. However, the Eastern Star and Sewol tragedies impart an important lesson for the passenger transport industry. They highlight the need for taking a system approach to the detection and prevention of breaches of safety constraints and calls for curative actions at both national and international level. Only then can we supersede the quick fixes of symptoms provided by individual components of the system and get to the true cure.

In the future, other socio-technical methods for accident investigation are suggested to be applied in such casualty analysis and, hence, may lead to more beneficial results.

7 Recommendations and conclusions

7.1Recommendations

The AcciMap not only analyses the route causes of the accident, but can also assist in concluding recommendations by classifying the causes. At least 8 aspects regarding enforcement gaps, regulatory gaps, unsuitable procedures, company negligence, training and qualifications, and license and market pressures have been identified and recommendations will be illustrated in Table 14 and Table 15.

Generally, in the Eastern Star case, from strategic design, policies should put safety management in domestic waters at an equal level to international areas for MOT. Standards of ship construction, especially while undertaking modifications, should be regulated in more detail for MIIT. IMO conventions or at least the principles for maritime safety should be made compulsory in domestic waters to avoid risks by MSA. Training for the crew of inland waterways should be strengthened in parallel. Local governments should be stricter and carry out effective surveillance in the future. A safety management system should be strictly followed, coupled with a tight assessment system by the ship's company.

For the case of the Sewol, the high level recommendations mainly focus on SAR and training due to the greater number of human factors involved in this accident compared with the Eastern Star.

Detailed recommendations are listed in Tables 14 and 15.

Table 14. Recommendations for Eastern Star

<table>
<tr><th>Catalogues</th><th>Causes</th><th>Recommendations</th></tr>
<tr><td rowspan="5">Enforcement gaps</td><td>Authorities did not notice the missing closing devices required by reg.</td><td rowspan="2">Authorities should be responsible and careful when making annual inspections and should follow up on ships with higher potential safety risks.</td></tr>
<tr><td>Authorities did not notice the ballast water modifications</td></tr>
<tr><td>Inadequate training for the captain and crew</td><td>Companies should strengthen training for their captains and crew. Sufficient simulations are necessary for staff on board to master the knowledge to handle all kinds of situations.
The authorities should organize some enforcement training programs and exams to test the capabilities of the crew.</td></tr>
<tr><td>Company did not report the modification to authorities</td><td rowspan="2">Ship companies should not hide anything related to safety for profit.
Serious penalties should be instituted on the companies if any enforcement gaps are found.</td></tr>
<tr><td>Company did not conduct effective tracking and monitoring of the ship</td></tr>
</table>

Regulatory gaps	No dynamic monitoring ship survey system	Dynamic monitoring ship survey system should be applied to follow up the conversions of ships.
	GMDSS equipment not required by regulations	Regulations for ships navigating inland waterways should be stricter. Technological standards should be improved to guarantee the safety performance of domestic ships.
	Authorities set operational limits at wind force BF 9	The navigation restriction when encountering adverse weather in Changjiang is suggested to be adjusted as follows: (1) a ship can not sail and should take effective measures to avoid strong winds when the wind force is forecasted over BF 7 (includingBF7) either at the departure port or the navigating routes. (2) When visibility at the departure ports is less than 1000 meters, the ship is prohibited from departing or leaving the port. When visibility during voyages is less than 1500 meters downstream or 1000 meters uplink, the anchor should be suspended.
	Escape routes were narrow following an earlier conversion	More stringent checks on ships should be made in the future.
Management gaps	Authorities did not supervise and monitor crew training	Necessary system for training should be set by authorities both for training and assessment.
Company	Automatic closing devices were not fitted	Companies should improve the level of safety management and self-checks.

negligence	to watertight doors	Authorities should regulate more strictly and make more inspections of the companies.
	Company manipulated ballast water tanks	
	Ship was not well maintained	
	Furniture in the cabins is movable	
Unsuitable procedures	VTS operator was not following the development	The duties and equipment on VTS should be strengthened. An effective and efficient emergency reporting system should be built to facilitate the SAR.
	Complicated procedure to alarm central SAR services	
Market pressure	Keep navigating in bad weather to catch the tourist plan	Profit pursuit should be balanced with safety management and safety should take the priority position.
	Cut the ship maintenance cost for lower ticket price	
License	Authorities issue water transport permit without careful survey	More stringent procedures should be taken before issuing permits and regular audits should be made after issuance.
Training/ Qualification	Unsuccessful attempts to maintain maneuverability	Training for improved knowledge and skills on manoeuvring should be strengthened.

Table 15. Recommendations for Sewol

Catalogues	Causes	Recommendations
Enforcement gaps	Authorities did not notice overload	Thorough improvements should be carried out on the entire safety control structure, proper measuring channel, such as feedback that reflects the effectiveness of safety constraints need to be designed for continuous improvement and corrective action (Kim, Nazir, & Øvergård, 2016).
	Authorities did not notice the falsified documents when registering	
	Vehicles were not well fastened	
	Watertight door was lashed open	
Regulatory gaps	Lower standards for the training of the captain and crew of domestic ships	The requirements for the captain and crew should be improved to an international level. The captain and crew should master knowledge and skills to cope with different situations. And they should know how to behave in an emergency.
Company negligence	Inadequate training for the captain and crew	
	Ship conversion causes the center of gravity to move upward	The safety limits of the vessel should be based on the shipyard's original design and the level of upgrading with respect to increased requirements or limits. A thorough risk assessment should be routinely carried out to ensure safe working practices. Continuous monitoring of risk and identifying potential areas of

		concern before they develop into hazards should be given priority. Constrain hazards before they lead to accidents.
	Rudder equipment malfunction Captain was not in the bridge during complicated situation	The ship's command should desist from taking risks and give absolute priority to the safety of the vessel and passengers, which also includes the securing of cargo and provision of a sufficiently intact lashing system in accordance with requirements to maintain ship stability.
	No effective evacuation was organized by captain	
Unsuitable procedures	Ship did not follow the route recommended by authorities	Establish integrated and corporate safety information system to maintain accurate process (mental) models of all system controllers to assist in decision making.
	SAR was not organized in time	Coast guard was cancelled after the accident for the negligence and a more scientific SAR was built in the Republic of Korea.
Training/ Qualification	Unsuccessful attempts to maintain maneuverability	Crew of Ro-Ro passenger ships should be properly trained for accurate and immediate actions during emergency, and should have clear instructions on maximizing their vessels' chances of survival in cases of water ingress to the car deck. The training should address day-to-day shipboard operations, risk assessment procedures as well as contingency planning and emergency
	Large rudder angle made the ship list heavily	
	Captain and crew took wrong measures in emergency	

	VTS operator was not following the development	preparedness.
Market pressure	Serious cargo overload	Profit pursuit should be balanced with safety management and safety should take the priority position. More stringent punishment regulations should be carried out in the future.

7.2Conclusions

Despite the endeavours of international organizations, flag and port administrations and classification societies in terms of promulgating regulations and requirements that make the maritime industry safer overall, the responsibility for ensuring the safety of ships, crew and passengers must initiate from the owners themselves. The reality calls for a cost-effective safety management approach that balances safety with economy, efficiency, and performance constraints, which do not cause the degradation of safety efforts over time.

After comparing several popular investigation methods, AcciMap was chosen as a harmonized approach to be applied in identifying and analysing the causes of the Eastern Star and Sewol accidents due to its advantages in organizational factor analysis and regarding recommendations to be formulated. Factual information was collected and ordered for the drawing of an ActorMap and AcciMap. ActorMaps were made to identify the actors involved in the accidents in order to prepare the draft of the AcciMap. Based on the investigation reports and factual information, AcciMaps of the Eastern Star and Sewol accidents were drafted separately. Relationships behind the root causes described in these two diagrams were illustrated according to the six levels of AcciMap. The six levels are listed as: topography and configuration of scenery and equipment, accidental flow of events and acts, technical and operational management involved, company management and local area planning, regulatory bodies and associations and government policy and legislation. These levels combined with cataloguing the causes can develop relevant recommendations. At the same time, a comparison of the two accidents was made from factual information and identified failures based on the AcciMap. The comparison listed the causes in tables, making it easy to find the similarities and differences in the two accidents. Further measures should be taken to prevent the repetition of accidents on domestic ships.

This research made some progress in the application of AcciMap in two significant events and provided some measures to prevent the repetition of similar tragedies in the future. However, further research is welcome to be developed due to the constraints both in the approach itself and information collection. The cases of the capsizing of the Eastern Star and Sewol ferry surely still have a lot of unsolved questions. This study provided some new insights to encourage further discussion and research into the establishment of effective measures for national and international maritime safety control and management.

References

Chen, Y. H., & Zhang, H. W. (2007). The guest rolls ponder the ship scene management by supervision graduation inspection pattern. *China Water Transport,7*(4).

Gao, Y. (2011). *A study on construction path for service-oriented maritime with public administration theories* (Doctoral dissertation, Dalian Maritime University, 2011). Dalian, China.

George, R. (2013). Ninety percent of everything: Inside shipping, the invisible industry that puts clothes on your back, gas in your car, and food on your plate. New York: Metropolitan Books/ Henry Holt and.

Han, Y. (2011). *Advanced grid mode in marine management* (Doctoral dissertation, Fudan University, 2011). Shanghai, China.

Harms-Ringdahl, L. (2004). Relationships between accident investigations, risk analysis, and safety management. *Journal of Hazardous Materials*, *111*(1-3), 13-19. doi:10.1016/j.jhazmat.2004.02.003

Hollnagel, E. (2012). *FRAM, the functional resonance analysis method: Modelling complex socio-technical systems*. Farnham, Surrey, UK England: Ashgate.

Hong, B. G., & Yu, Y. (2000). Safety assessment of Ro-Ro passenger ship. *Journal of Dalian Maritime University, 26*(2), 44-47. doi:10.3969/j.issn.1006-7736.2000.02.012

IMO. (2008). *Casualty investigation code: Code of the international standards and recommended practices for a safety investigation into a marine casualty or marine incident*. London: International Maritime Organization.

IMO. (2016a). *Status of Conventions: Summary of Status of Conventions*. Retrieved from http://www.imo.org/en/About/Conventions/StatusOfConventions/Pages/Default.aspx

IMO. (2016b). *GISIS: Marine Casualties and Incidents – Casualty Data from IHS*. Retrieved from https://gisis.imo.org/Secretariat/MCI/IHSData.aspx.

Jalonen, R., & Salmi, K. (2009). *Safety Performance Indicators for Maritime Safety Management*. Helsinki: Helsinki University of Technology. Retrieved from http://www.merikotka.fi/metku/TKK-AM-9-1.pdf

Ji, H. (2015). Safety supervision and management of smaller inland vessels. *Technology Outlook, 27*.

Kim, T., Nazir, S., & Øvergård, K. I. (2016). A STAMP-based causal analysis of the Korean Sewol ferry accident. Safety Science, 83, 93-101. doi:10.1016/j.ssci.2015.11.014

Lee N., V. H., Donald K, L., & Randal L, M. (2005). *Root cause analysis handbook: A guide to effective incident investigation* (3rd Edition ed.). Brookfield, CT: Rothstein Associates.

Li, B. Q., & Jin, H. H. (2009). Explore new paths on Ro-Ro passenger ship safety management. *Marine Fire, 3,* 36-39.

Li, Z., & Wu, S. (2014). Analysis on the Causes of Sewol. China Water Transport, 14(10), 53-55.

Liu, D. (2015). Research and discussion on domestic cruise ships safety supervision. *China Water Transport, 15*(11), 77-78.

Liu, G. C. (2002). Strengthen safety supervision and administration of marine Ro-Ro Freighters--On the promulgation of the provisions of. *Modern Occupational Safety, 7*. doi:10.3969/j.issn.1671-4156.2002.07.021

Liu, Z. J. (2010). The trend of Ro-Ro passenger vessel development: lessons learned from the new safety measures adopted by IMO to enhance the Ro-Ro passenger ship safety. *China Maritime Safety, 1*.

Mi, T., & Zhao, Q. (2015). Some Ideas about the Sewol Accident. Navigation Technology, 1, 67-69.

Quan, Y. Z. (2010). The analysis of situation and development of Ro-Ro passenger ship transportation in China. *China Ports, 5*, 55-56.

Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. *Safety Science, 27*(2-3), 183-213. doi:10.1016/s0925-7535(97)00052-0

Reason, J. T. (1997). *Managing the risks of organizational accidents*. Aldershot, Hants, England: Ashgate.

Salmon, P. M. (2011). Human factors methods and accident analysis: Practical guidance and case study applications. Farnham: Ashgate.

Schröder-Hinrichs, J. U., Baldauf, M., & Ghirxi, K. T. (2009). Accident reporting deficiencies related to human and organizational factors in engine room fires on board ships. *Theory and Applications Reliability, Risk, and Safety*. doi:10.1201/9780203859759.ch37

State of Administration of Work Safety. (2015). *Number of marine casualties and incidents in Changjiang 2010-2014*.

Svedung, R. &. (2000). *Proactive risk management in a dynamic society*. Karlstad: Swedish Rescue Services Agency. doi: https://www.msb.se/RibData/Filer/pdf/16252.pdf

UNCTAD. (2015a). *UNCTADSTAT: Gross domestic product: Total and per capita, current and constant (2005) prices, annual, 1970-2014, (figure 1)*. Retrieved from http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=96

UNCTAD. (2015b). *UNCTADSTAT: World seaborne trade by types of cargo and country groups, annual, 1970-2014*. Retrieved from http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=32363

Underwood, P., & Waterson, P. (2013). Systemic accident analysis: Examining the gap between research and practice. *Accident Analysis & Prevention, 55*, 154-164. doi:10.1016/j.aap.2013.02.041

Wu, Y. (2014). Research On The Causes Of The "SEWOL" Accident. Journal of Nantong Vocational & Technical Shipping College, 13(3), 24-26.

Xu, H. (2015). Research on the Emergency Response and Rescue of Sewol. China Emergency Rescue, 1, 39-41.

Yu, H. B. (2008). *SWOT Analysis and Countermeasures on Shenzhen maritime management* (Doctoral dissertation, Fudan University, 2008). Shanghai, China (CHN).

Zhang, J. (2001). Strengthening safety management for inland navigation vessels. *Ship Safety and Countermeasures in case of storm Proceedings*.

Zhang, J. P. (2010). A regularity study on the safety control of Ro-Ro passenger ships in the Bohai Bay. *China Maritime Safety, 1*.

Zhang, Z. J. (2014). The analysis on technical condition of domestic passenger ships. *China Ship Survey, 9*, 82-84.