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Human intervention in maritime safety accidents

Qinyan Sun

WORLD MARITIME UNIVERSITY

Shanghai, China

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By

SUN QINYAN

China

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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.

(Signature): ________________________

(Date): ________________________

Supervised by: ________________________

Supervisor's affiliation ________________________

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Abstract

In the shipping industry, safety should always be taken as the first priority or it will lead to numerous losses in various fields. At the same time, when the accidents happening in the sea, it will also bring about a painful price, sometimes much heavier than those on the land. It may cause heavy casualties and it is difficult to find missing people in the sea when accidents happening. Besides, it will also require huge costs for the maintenance of the ship after accidents. Based on these reasons, I would like to find out whether the whole world can do something to relive this phenomenon.

In my thesis, I choose firstly to point out the harm of the accidents which may bring to people even to the whole society in different fields including economy, physical health, mental health, etc. After that, for those marine accidents, I introduce some effective precautions for those frequently occurring accidents. To provide some detailed information about analyzing and preventing the accident, I introduce four models in my thesis including energy-barrier model, MMD model, HRO model and McSween's safety model, which are all helpful to find out the contributing factors of the accident and also provide some effective measures to reduce similar accidents happening again so as to really improve maritime safety. The discussion part examine the importance of the application of those effective models so as to truly prevent the occurrence of accidents and improve maritime safety.

KEYWORDS: Maritime accidents, Precautions, Models, Safety improvement

Table of Contents

List of tables

List of figures

List of abbreviations

TSB	Canadian Transportation Bureau of Safety
MMD	Man made disasters theory
HRO	High reliability organization theory
TC	Transport Canada
SIRS	Ship Inspection Reporting System
ATSB	Australian Transport Safety Bureau
BV	Bureau Veritas
ECDIS	Radars, electronic chart display and information system
BRM	Bridge resource management
VTSO	Vessel traffic service officer
SMS	Safety management system

1. Introduction

1.1. The harm of accidents

We hope accidents never happening, while the fact is that accidents frequently happen on a daily basis. In general, some accidents such as fire disasters, transportation accidents, explosion, oil leaking always happen, leading to great losses to people even to the whole society in economic, physical and mental health, etc.

In terms of maritime safety accidents, several accidents should be recorded in the statistics of maritime accidents including collision, stranding, swell damage, fire and explosion, wind damage, sinking, other maritime accidents causing casualties and direct economic losses according to the requirement of the Ministry of Transportation of the People’s Republic of China. Through the statistics of casualties and economic losses, the accidents can be classified into several grades including minor accidents, general accidents, large accidents, serious accidents and super accidents.

In accordance with Summary Marine Occurrences issued by Canadian Transportation Bureau of Safety(TBS), the data indicates that collision accounts for 21% among the total accidents investigated, stranding represents 20%, and the fire disaster occupies 11%. Besides, according to the report issued by Norway Maritime Administrative Bureau, stranding ranks first among all the accidents, representing 45.7%, while the collision between vessels or between vessels and other objects occupies 30.5%.

As for the maritime safety accidents, first of all, they will result in severe human casualties, even more serious than those in the general accidents. When the maritime accidents happen, the salvage will be more difficult than that on the land. And it is also difficult to find the missing people in the sea. After experiencing the maritime accidents, even without physical injuries, people may also shoulder mental harms. During the salvage, it may cause huge labor and economic losses. After the accident, the repairing or modification of the vessel also costs a great deal. As is known to all, the cost of one vessel is extremely high. Besides, environmental problem has been focused on by increasing people. Nowadays, various companies endeavor to develop vessels with zero or few emission, limiting the emission of harmful gases. In this perspective, after the accident, it will greatly harm the environment.

Through those sides, we can find that the results caused by accidents are extremely severe, which deserves to be paid more attention to and to take corresponding measures.

1.2. Precautions of marine accidents

1.2.1. The analysis of root causes of common maritime accidents

In terms of those traditional maritime accidents, the authorities identify the root causes from several perspectives. First of all, it is due to human factor. Human factors are mainly composed of the lack of professionalism and the fatigue of crew members. Take one accident as an example, two vessels collided, resulting in the sinking of one vessel. The accident happened because the master of one vessel hadn't recognized the dangerous situations of collision, taking inappropriate measures and keeping the unsafe speed during emergency. One another example is more ridiculous that one oil tanker collided the shore due to drunkenness of the master. After that, the third mate lacked experience and failed to immediately swerve, resulting in the disaster. From these two examples, we can find that the quality of the crew members is of great importance.

Environmental conditions can be another cause leading to the accident. Environmental conditions include hydro meteorology, seaway environmental conditions, transportation environmental conditions, etc. In 1999, the passenger vessel ACHAT made collision with HANJIANG 21, leading to the death of 3 people, the loss of 1 people and the injury of 2 people. The collision was caused by the environmental conditions. That day, the thick smog appeared, leading to low visibility, which was the reason of difficult watching and estimation of collision. In this side, to avoid accident, sailing should better be taken in some favorable weather.

In 1998, JIAYU capsized during the period of loading the cargoes, resulting in the severe maritime accident. The root cause was due to the original drawback of the vessel structure, then the low stability together with other outside factors resulted in the disaster. This showed that poor vessel conditions can also lead to severe maritime accidents, deserving to prevent. Hence, regular inspection of the vessel should be taken to avoid emergency.

1.2.2. The solutions to the common maritime accidents

Maritime accidents frequently happen, so effective measures need to be taken. Only with the contributing factors of the accident can not improve maritime safety.

To begin with, the maritime accident big data needs to be constructed. The big data can be the foundation for avoiding further maritime accidents. Through analyzing the big data and setting up safety suggestions can be the helpful tool for avoiding similar disasters happening again, as well as standardizing the acts of enterprises and seafarers.

Next, it is necessary to promote safety culture. Through this step, it can make contributions to fulfill the goal of achieving zero accident and injury of the maritime industry, promoting the seafarers to take safety and marine environmental protection as the first priority.

Then, the management of seafarers need to be advanced. In this side, the profession of seafarers should be promoted such as getting extreme with the structure of the vessel, emphasizing on the inspection of the vessel, as well as the maintenance of the equipment, etc. Besides, the overall quality of seafarers should also be improved such as the rapid response and mental quality of seafarers during emergency.

Last but not least, it is the responsibility of relative departments to construct safe and structured outside environment, reducing the occurrence of maritime accidents. The efforts of seafarers and the crew members did impose great effects on reducing maritime accidents, while the safe overall environment can be the foundation for further improvement.

2. Literature review

2.1. Findings through articles by other authors

Some researchers state that the collision between the ship and the bridge is frequent, while the huge quantity of ships, the low quality of the bridge as well as the weak safety awareness of drivers can also aggravate accidents (Zhang Jianlin and Zhou Haibing,2017). In the study of another researcher, he analyzes 3 cases of accidents, the spilling of the oil, the capsizing and sinking of ships, indicating direct and indirect reasons for these accidents from technology, management, crew quality to weather. He warns that we need to find out root causes and then to strengthen management and improve emergency measures as well. (Peng Guosheng,2012).

Besides, the surveys on maritime accidents are of great significance. During the surveys, direct proofs are not the single thing to be concerned, root causes are the most important things. These causes should include direct ones and indirect ones as well, focusing on the whole responsibility chain (Na Jichao,2010). International Maritime Survey Rule claims that the severe accidents causing the overall loss of the ship, heavy casualties and pollution should be surveyed. For those slight accidents, if key reasons are evaluated to be conducive to future precautions, relative sectors should also be encouraged to carry out surveys (Xu Chun,2017). When implementing survey, China should learn from some advanced facets of America including separating technical from administrative survey, gradually making surveys public and speeding up the construction of maritime labs (Huang Jie,2016).

Maritime standards are vital to avoid accidents, while they also appear due to occurred accidents. When making precautions, risk assessment can be helpful. From this perspective, qualitative and quantitative assessments are both necessary to identify hazards, evaluating following effects (Liu Xiaodong and Mo Danfeng,2010).

In 2018, since typhoon landing on China, Guangdong Maritime Board carried out precautions, ensuring every ship entering safe waters to get rid of typhoon in order to avoid accidents. Besides, the board also sent professional salvaging vessels to protect some focused ships in the dangerous waters, achieving zero casualty and accident (Zhang Jianlin, Zhou Minyao and Dengmin,2018).

Looking around the world, resolving the problem of maritime safety, the channel of law should be realized. And only with outer dispute coordination as well as inner institution completion can the effective and safe marine transportation passage be constructed (Yang Xianbing,2017).

One passage deeply identifies the root causes of common maritime accidents and achieves the solutions to these accidents so as to reduce the occurrence of accidents. The author deeply analyzes the cause of the accident from three sides including human, environmental and vessel factors. (Lian Jingjing, Yang Xiao,2017).

One author finds that the cause of most injuries can be attributed to at-risk behavior or insufficient safe behavior. He not only instructs principles and practical procedures for improving safety-related behaviors, but also illustrates how to increase people's willingness to use these techniques to create a Total Safety Culture (E.Scott Geller,2001). In the book of VALUES-BASED SAFETY PROCESS, the author indicates that the effective culture is conducive to safety management, and the key to a successful behavioral safety process is gathering the right teams together to plan the implementation. In the specific implementation process, there exists several useful stages such as the safety assessment, executive overview, establishing mission, values, and milestone targets, creating safety observation process, designing feedback and involvement procedures, and design team workshop, establishing safety incentives, implementing behavioral safety process as well as maintaining behavioral safety process (Terry E.McSween,2003).

The Marine Investigation Report issued by Transportation Safety Board of Canada introduces the accident with detailed information focusing both on behaviors and conditions, identifies the root causes as well as the risks leading to accidents, and achieves the solutions to the problems emerged from the accident. (Transportation Safety Board of Canada,2014). The report gives the idea about how to appropriately analyze the accident for further advancement. ATSB Transport Safety Report shows one grounding accident about the vessel owned by Maersk, collecting deep information about the accident and analyzing the contributing factors to the grounding for further avoiding (Australian Transport Safety Bureau,2016).

Besides, one passage published in Safety Science presents the structure from the introduction of the accident to further analyzing the accident by different theories, then making the comments on the accident. (Kim Hyungju, Haugen Stein, Utne Ingrid

Bouwer, 2016). This passage helps me to be more clear about the approach to analyze the accident. It should be presented in several facets, from the introduction, details about the accident, to the statement of the theory or model, and the application of the model to the accident analyzing.

2.2. Conclusions on literature review

Through consulting literature, I find that increasing people focus on maritime accidents, hoping to find root causes and the solutions to them. These articles deeply analyze the reasons of frequently occurred maritime accidents from extensive perspectives, while the solutions in these articles are not extremely specific, just talking in generalities.

On the other hand, when looking through the book of VALUES-BASED SAFETY PROCESS and The PSYCHOLOTY OF SAFETY HANDBOOK, I find that these two books pay more attention to the methods to reduce the accidents in the enterprises. These methods are effective and specific, while not focusing on the maritime industry.

In my opinion, few literature or book closely connects these two parts, so I endeavor to make the root causes to the maritime accidents and methods in close-knit relation to each other. Hence, in my thesis, different from most of other articles, I would like to introduce frequent occurred maritime accidents firstly, then demonstrating some effective methods to reduce accidents in different areas, finally showing how to apply these methods to actual maritime accidents to get rid of similar accidents. In terms of actual maritime accidents, I would like to mainly find detailed information from the relative websites to China Marine Board and regional Marine Board, as well as the official accounts set by the Marine Board. Besides, I also want to search for some cases from the thesis published by other people such as someone working in the maritime field. I will extensively search for actual cases, selecting some typical cases to analyze the situations of those cases.

In my thesis, I choose some theories introduced in the passage published on Safety Science, which has been mentioned previously. Having a look at those theories, some ones are suitable for the typical maritime accidents I find, while some are not. Hence, I combine three theories in this passage with McSween's safety model to analyze the 2 accidents I find.

3. The introduction of different theories for analyzing accidents

Various researches have been carried out to analyze the maritime accidents and find some solutions to reduce similar accidents occurring. In my thesis, I will introduce four theories to analyze the maritime accidents so as to improve the maritime safety.

3.1. The energy-barrier model

First of all, the energy-barrier model, which indicates that the failure of effective applying energy barriers that are likely to reduce the occurrence of accidents affects the outcome to the accident to some degree.(Kim Hyungju, Haugen Stein, Utne Ingrid Bouwer,2016). In this way, energy barriers may sound difficult to understand. In other words, it means some actions to prevent a few severe incidents happening. For instance, the severe incident in one case may be collision, so the energy barriers may lay on how to prevent those severe incident happening. And for those actions, they may also related to some people or departments to organize. These should all been considered in the energy-barrier model. And in this model, some components should be focused on. The first component is the barrier function, representing one function that is used to prevent the occurrence of some disasters such as capsizing, collision, etc. Next, for those barrier functions can be divided into barrier sub-functions, considering how to reduce the probability of accidents in a more detailed way. Barrier system can be regarded as the third component, which is a system set to implement those barrier sub-functions. The fourth one is barrier element, indicating some people or organizations related to specifically implement those barrier systems. Hence, it is obvious that these components are closely connected with each other. Key components and their corresponding sequence can be seen as figure 1.

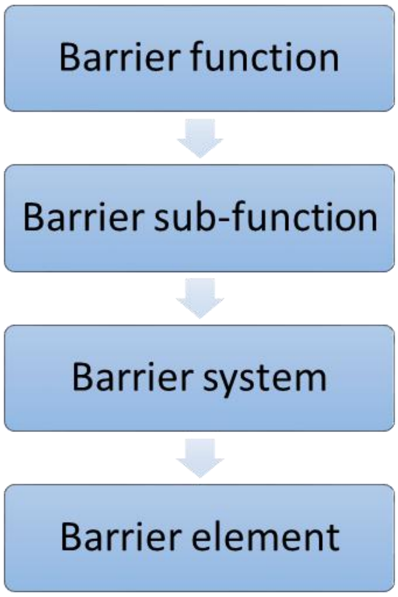

Figure 1. Key components of the energy-barrier model

Source: Assessment of accident theories for major accidents focusing on the MV SEWOL disaster: similarities, differences, and discussion for a combined approach, 2016.

3.2. Man made disasters (MMD) theory

Secondly, man made disasters (MMD) theory. It is obvious through its name, mainly resulting from human beings. Sometimes accidents happen not due to some natural disasters or the engine failure, but because of human neglecting. Before navigation, some people may know about the hidden dangers of the vessel, but they don't choose immediate actions to improve the condition, but neglecting those hidden risks, not willing to consider the worst side(Kim Hyungju, Haugen Stein, Utne Ingrid Bouwer, 2016).

In this theory, it begins with the initial common belief of relative personnel and departments about the hidden risks of the ship or the voyage and also for the corresponding measures. Then, it comes to the shortage of information exchange among people. It means that some people may recognize the hidden dangers of the vessel or some problems probably occurring, but they don't choose to share the information with other people due to the culture of the company as a few of companies are reluctant to consider the worst thing. And this theory is mainly applied to analyze those unexpected accidents. When the unexpected event happens, relative personnel then immediately adjust the original recognition and make corresponding improvements during rescue. Below figure 2 can indicate the major steps when applying MMD model to analyze accidents.

Figure 2. Major steps of MMD model for analyzing accidents

3.3. High reliability organization (HRO) theory

Next, high reliability organization (HRO) theory. This theory helps to show us the accidents may happen, while extremely severe accidents may seldom happen.(Rosness et al.,2010). It is because the people who confirm with the standards of HRO theory may always pay more attention to those hidden risks from past experience, and will be carefully committed to their tasks. In this perspective, those people representing HRO theory are a bit contrary to those implementing MMD theory. In this theory, different experts may list different key points in this theory. In my opinion, this thesis upholds one view that is to divide the analyzing process of HRO theory into two parts, "the ability to forecast the precipitating event" and " the ability to control and relieve the unexpected".

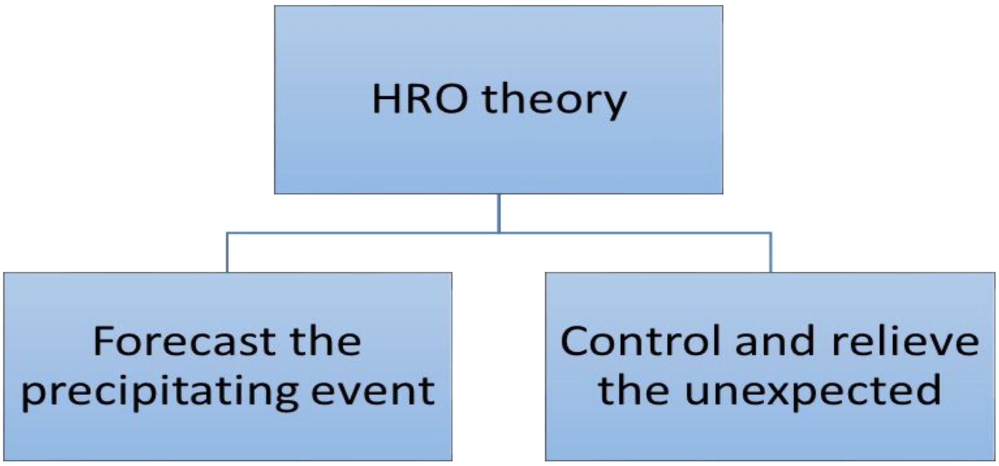

Figure 3. Key points of HRO theory

3.4. McSween's safety model

Finally, according to McSween's model, McSween claims that the key to the successful safety process is to construct a layered team structure. (McSween,2003). McSween's safety model combines the importance of unsafe conditions and behaviors, different from the traditional ideas of other people claimed in safety. As for McSween's model, he firstly implements the safety assessment, which is a useful tool for achieving the general contributing factors of the accident, then through safety meeting, getting the plans for these problems. Secondly, the executive and design team both play important roles in this link. Next, during the period of final design, it requires several steps. In general, it needs the executive team to lead the investigation and also make reviews, several rounds of safety meetings for brainstorming the root causes to the accident and corresponding plans. Then, it is a must to implement all the safety processes and maintain them to improve the safety conditions and reduce the accidents.

This is a model regarding how to implement and maintain safety in the working places while not paying attention to interpret the accident through its whole period.And below table 1 presents the whole process of McSween's safety model.

Table 1-The critical components of McSween's safety model

Step	Behavior
Step 1	The safety assessment
Step 2	Executive overview and design team workshop
Step 3	Establish mission, values and milestone targets
Step 4	Create safety observation process
Step 5	Design feedback and involvement procedures
Step 6	Develop recognition and celebration plans
Step 7	Plan training and kickoff meetings

Step 8	Conduct management review
Step 9	Implement behavioral safety process
Step 10	Maintain behavioral safety process

Source:Values-Based Safety Process: Improving Your Safety Culture With Behavior-Based Safety, 2003.

3.5. The reason for choosing these four models

Firstly, the ultimate goal of choosing models to analyze accidents is the same, to reduce the occurrence of accident and then to improve maritime safety. To better analyze the accidents in a more detailed way, I choose four models from different perspectives. The energy-barrier model focuses on capturing those functions and systems preventing the occurrence of the disaster. This model helps to analyze the major causes related to the accident, and prevent this kind of accidents from the source. MMD theory pays more attention to interpret the accident from people, the lack of information exchange among people. To some extent, the availability of this theory may be less than the previous one as it mainly focuses on people. Besides, this model upholds that when the unexpected happens, the view shall be changed during rescue period, so it fails to analyze those accidents with poor rescue mechanism. HRO theory interprets the accident from two parts, the previous precaution and the latter control. And the main difference of this model is that this model inclines to interpret the accidents not quite severe, so the analyzing of severe accidents with huge fatalities should be ignored in this model. Then, McSween's model, unlike previous models, more like one textbook for instructing people the whole stage of improving safety, not aiming to interpret the accident. In my thesis, I mainly apply this model to interpret the measures taken by some relative organizations after the accident to avoid this kind of accident again. And for the previous models, I apply them to the whole accident analyzing from the initial situation before voyage to the rescue linkage.

In my opinion, accidents may be various, and even in one accident, contributing factors may also be multiple. Hence, interpreting the accident by different models may achieve more overall conclusion and then take more effective measures to reduce the accident and enhance safety. Although the focus of these models is various, the ultimate objective is the same, for the global maritime safety.

4. Case analysis Ⅰ -The fire explosion and abandonment of La Releve II

4.1. Introduction of the vessel and the accident

4.1.1. Brief description about the La Releve II vessel

A local family-owned energy distribution company purchased the passenger vessel in 2010, and the vessel was then used for daily excursions seasonally.

The passenger vessel is composed of 2 decks, made of wood and covered with fiberglass. As for the upper deck, it is open for installing seats for passengers. The vessel is powered by a diesel engine, which is located in the compartment amidships(Marine Investigation Report M14C0156, 2014).

Detailed information of the vessel can be shown as table 2.

Table 2-The detailed information about La Releve II

Name of vessel	La Releve II
Official number	802585
Port of registry	Quebec,QC
Flag	Canada
Type	Passenger vessel
Gross tonnage	37.09

Length	16.62m
Built	1983
Propulsion	1 diesel engine driving a fixed-pitch propeller
Maximum complement	47 passengers and 2 crew
Complement at occurrence	33 passengers and 2 crew
Registered owner	Air Richard Propane Inc.
Manager	Services Maritime Boreale

Source: Marine Investigation Report M14C0156, 2014.

4.1.2. Brief description about the La Releve II accident

On 16th April 2014, the passenger vessel La Releve II suffered fire explosion in its engine compartment, which was later extinguished by the crew members, while still resulting in the injury of one passenger. The fire started at about 13:35 Eastern Daylight Time on its tour along Havre-Saint-Pierre. During the accident, the passengers were evacuated to 2 life rafts of the vessel, then transferred to 2 commercial vessels.In total, there were 33 passengers and 2 crew on the vessel. After evacuation, there were two passengers sent to the hospital for aid. One of them received shock and recovered soon, while the other people suffered a leg injury, still sustaining when boarding the port life raft.(Marine Investigation Report,2014).

The lack of coolant resulted in the overheating of the engine, causing the severe damage to the engine. Besides, several equipment failed to use continuously due to the fire. After the incident, the owner of the vessel, who was also the authoritative representative of the vessel, stopped the vessel for service.

Transportation Safety Board of Canada (TSB) implemented the investigation on the accident for further maritime improvement instead of blaming on specific people.

TSB concluded that the fire of the vessel was firstly caused by the lack of coolant in the engine, resulting in the crack. Then, the crack in the manifold together with the damaged hose caused the breakage of the insulation, further bringing about the exposing of the layer of polyurethane foam. After the foam turned soaked in oil and mixed in the hot exhausted gases, the fire then started in the engine compartment.

And the specific timeline about the accident can be shown as below.

At 12:00, 2 crew members, the master and the deckhand made preparation before departure.

At 13:05, the vessel started from Havre-Saint-Pierre marina towards Mingan Archipelago.

At 13:35, the master broadcast for informing the passengers that a fire started and they decided to abandon the ship.

At 13:43, the master informed MCTS Rivere-au Renard that 90% of passengers had been evacuated to the 2 life rafts.

At 14:02, the final passenger was successfully evacuated to another passenger vessel(Marine Investigation Report, 2014).

The deeper analysis of the accident can be viewed as below sections.

4.2. The fire explosion explained by the energy-barrier model

The energy-barrier model helps people to construct energy barriers so as to reduce the occurrence for those accidents such as collision, grounding, fire explosion, etc.

As for the barrier functions, they are set between the beginning event such as man-made mistake or engine failure increasing the possibility of the accident and the consequence of the accident. And the barrier functions can be divided into contrary sides including proactive and reactive ones, positive and passive ones, etc.

In accordance with the MARINE INVESTIGATION REPORT M14C0156 issued by Transportation Safety Board of Canada, the fire began resulted from the absence of coolant of the engine, which has also been covered in the previous section.

“Losing coolant of the engine” is the beginning event, “fire explosion” is the perilous event, as well as “the injury of 1 passenger and the damage of the vessel’s engine and engine compartment” is the result of the accident of LA RELEVE II.

In this accident, we should only discuss it with the proactive barriers between the initiating event and the perilous event,as the proactive barriers in this case are more representative and straightforward. Besides, the damage of the engine and engine compartment as well can not be singly reduced, and should be reduced through the linkage of proactive barriers, so in this part I will only include the proactive barriers to analyze the accident. After the occurring of the beginning event, the fire explosion can be restrained by the proactive barriers. However, in the accident of LA RELEVE II, those proactive barriers didn’t function.

The below figure presents the proactive barrier “prevent fire after the lack of coolant of the engine”, which can then be subdivided into three sub-functions “prevent the use of thermal-acoustic insulation”, “keep space materials with low-flame spread” and “keep alarms and temperature gauges available”. Besides, every sub-function holds the corresponding barrier system, which can also be divided into several barrier elements.

The sub-function “prevent the use of thermal-acoustic insulation” can be achieved by the barrier system “insulation estimation and inspection”, of which the barrier elements are “engineers of the shipowner” and “inspectors of Transport Canada”. Transportation Safety Board of China stated that thermal-acoustic insulation such as aluminized Mylar may aggravate the deterioration to the engine as well as the fire. In accordance with TSB Aviation Investigation Report A98H0003, this kind of insulation, Mylar was forced not to be used after the Swissair Flight 111 accident. In this case, the passenger vessel still chose this type of insulation. In conclusion, the vessel had the hidden risk for insulation before sailing.

“Keep space materials with low-flame spread” is the second barrier sub-function. For this sub-function, the barrier elements are the same as the previous one. In this case, the material wasn’t carefully considered for the passenger vessel. If the material is not with low-flame spread, it will produce more smoke exacerbating fire explosion.

“Keep alarms and engine temperature gauges available” is another barrier system. Meanwhile, the barrier elements are also the same. During emergency, if the alarm works, the master or related employees can take timely measures to prevent the accident from worsening again. However, in this case, according to the investigation by TSB, they found that there were no alarm to warn the master about the engine problem. Besides, for the temperature gauges indicating the situation of the engine, only one of the three gauges worked, while the gauge required the person to bend down to watch the temperature, which was not very obvious and convenient.

The relationship of energy barriers can be shown as figure 4.

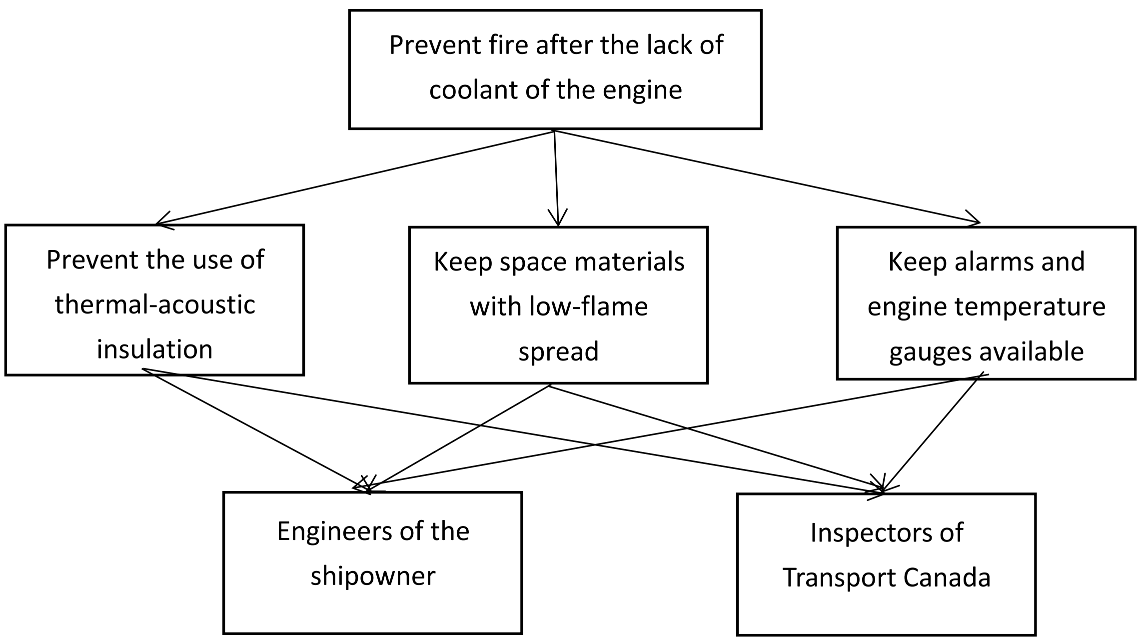

Figure 4-The items related to energy barriers in La Releve II accident

The energy-barrier model clearly shows us the whole linkage of LA RELEVE II accident. In other words, what action leads to what result. In this case, the accident happened leading to fire explosion and final vessel abandonment due to the absence of effective energy barriers. Through the lesson of the accident, it can be found that with the help of the barrier sub-functions including “prevent the use of thermal-acoustic insulation”, “keep space materials with low-flame spread” and “keep alarms and temperature gauges available”, the fire maybe distinguished in a shorter time, which will not lead to the severe damages to the engine and the engine compartment, even the abandonment of the vessel.

In terms of the energy-barrier model, analyzing and improving the availability and effectiveness of the barrier functions can be conducive to reduce similar accidents or the harm when similar accidents occurring.

4.3. The fire explosion explained by man made disasters (MMD) theory

In the perspective of MMD theory, it focuses on a series of incidents instead of some single things such as the natural breakage of the engine, the harmful environmental disaster, etc. It is always considered that someone in the organization may have the idea of the hidden risks of the sailing such as the problem of the engine, while the organization takes no action in this part due to the organization doesn’t receive corresponding effective information from the people who are clear about the fact. The MMD theory can be analyzed from several parts including the initial recognition taken by relative people, the lack of information exchange, the unexpected precipitating event and readjustment after the unexpected event during rescue.

For each step, the detailed information will be analyzed as below.

4.3.1. The initial common belief taken by relative people

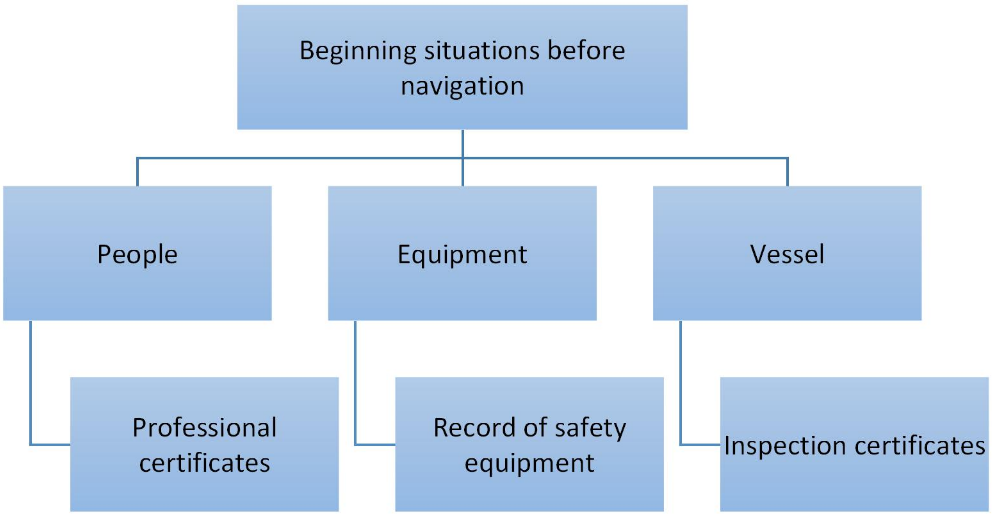

Figure 5-The analysis of beginning situations in La Releve II accident

The structure of beginning preparation and situations of this case can be seen from above figure 5.

Before the occurring of the accident, safety had always been focused on by the whole society. TSB always issued the report of various accidents and the corresponding measures to mitigate the similar accidents.

As for the master and the deckhand, both of them held corresponding certificates supporting them for sailing. The vessel held sufficient certificates issued by Transport Canada (TC) before departure. TC implemented annual inspection to the vessel and then issued annual certificate to the vessel. In this perspective, the fire inspection is one part, and the fire detection system was inspected to be in a favorable condition by the owner of the vessel with the observation of the inspectors of TC. Besides, as for the equipment, the vessel was also provided a Record of Safety Equipment together with the certificate to inform the owner and the master of the safety equipment required to be taken.

4.3.2. The lack of information exchange among people

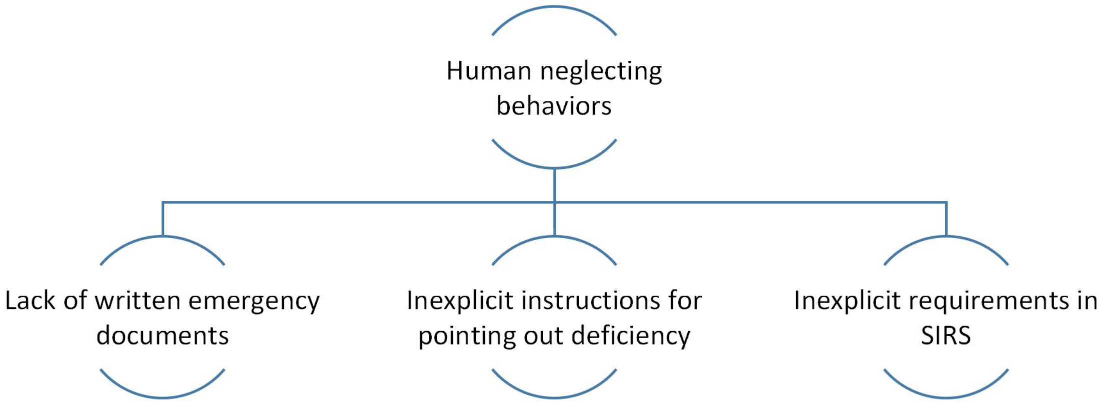

Figure 6-Human neglecting behaviors in La Releve II accident

Above figure 6 can clearly summarize those human neglecting behaviors in this case.Through analyzing the accident, it is conducive to prove that some hidden risks exist as people always neglect them and minimize the harm of those risks may produce to the accident.

When the accident happened, it proved that the relative employees overlooked the harm of the accident during emergency. Before sailing, several hidden risks were provided by TC for the owner to improve, while the owner knew these problems but didn't choose to make corresponding advancement until departure.

The crew members of the vessel didn't have written emergency documents. And the fact is that during emergency, the crew members were not quite familiar with the specific procedures for evacuation, and they failed to help the passengers wear the life-saving jackets. Although it didn't cause severe results in this accident, it did exist hidden risks. It may slow down the speed of evacuation, which may increase fatalities when the accident happens.

Besides, there didn’t exist specific instructions or regulations for TC to ensure what kind of deficiency can be defined as severe problem, and to identify what qualification of the vessel meets with can be issued the certification. Furthermore, the Ship Inspection Reporting System (SIRS) didn’t include explicit requirements for TC to observe during the inspection to the vessel, which may increase the possibility that the vessel can still receive the certificate for sailing even with severe deficiencies(Marine Investigation Report, 2014).

4.3.3. The occurrence of unexpected event

As for this case, both the vessel and the crew members held the corresponding certificates, as well as the shipowner or the crew members all knew about the risks of the passenger vessels for TSB published accidents about passenger vessels before for notice. Hence, the accident was an unexpected event. The original cause, the lack of coolant became the blasting fuse leading to the fire explosion.

4.3.4. Readjustment of recognition after the accident during rescue

Rescue is also an important stage for analyzing when applying the MMD theory to the accident. MMD theory indicates that when the precipitating event really occurs, during evacuation, people may revert their mind to mitigate the adverse affect of the accident.In this case, during rescue, some behaviors of the crew members were good, while some of the behaviors were not fairly suitable, which could be improved. And the general summary of those rescue behaviors as well as their comments can be shown in table 3.

Table 3-The analysis of rescue behaviors in La Releve II accident

Item	Rescue behaviors	Performance	Comments
1	Contacting the rescue team	Good	The master immediately contacted the rescue team for evacuation assistance.
2	Launching life rafts	Poor	Two of the three life rafts were available for use.
			The number of life rafts was more than that of crew members.
3	Evacuation implementation	Poor	The crew members were unfamiliar with the emergency evacuation procedures.
			The crew members were unsure about the instructions of launching life rafts.
			The crew members didn't alert the passengers for fire notice.

The lack of coolant was the initial cause of the accident, bringing the fire explosion, which was an unexpected accident. As for this accident, one passenger was injured, so the whole rescue process confirmed with satisfaction. During evacuation, although the master contacted the rescue team for evacuation timely, there also appeared a few problems.

When using the life raft, 3 life rafts were equipped on the vessel, while only 2 of them were applicable. Furthermore, only 2 employees were on the vessel, so 2 life rafts on the vessel were more suitable because no one else knew clearly about the use of life rafts. In terms of emergency actions, there were no written emergency procedures on the vessel, so the master and deckhand took spontaneous actions, while they were not familiar with the right order of the evacuation process. Even during emergency, the passengers were not alerted by the employees, but knowing that from the sign of smoke and fire. Besides, the deckhand was not sure about the instructions of the master when launching the life raft.

4.4. The fire explosion explained by high reliability organizations (HRO)theory

The critical point of HRO theory is that the theory focuses on answering the question why those severe accidents seldom happen, and if accidents happen, why mostly they include those minor accidents. To some degree, the idea of the theory for identifying the problem is relatively rare and new. Due to that, some authors point that the HRO theory may lack something important within the organization, as it fails to analyze those severe accidents. From my perspective, it did exist limitation, while it can interpret the accident of LA RELEVE II as the accident did not suffer severe fatalities. If one person is HRO, they should anticipate the hidden dangers from past experience, even for those near miss, and take some immediate actions to avoid those dangers occurring on their own sides. Besides, if emergency really happen, they may have held the capacity to resolve the problem, controlling and reducing the harm to the lowest level through their high expertise and rich experience.

Then, my analysis will focus on who and what behavior confirming with HRO as well as those not confirming with HRO. From my perspective, through the sides of precautions and controlling of emergency, the master and deckhand were partly HROs, and partly not HROs, and the shipowner and TC as well were not HROs.

And the brief classification of people and behaviors confirming with HRO or not can be seen as below table 4.

Table 4-HRO analysis in La Releve II accident

	Relative personnel	Behaviors
Confirming with HRO	The master and deckhand(partly)	Despite some minor mistakes, the crew members successfully evacuated all the passengers.
Not confirming with HRO	The master and deckhand(partly)	The crew members weren't familiar with evacuation procedures and life raft instructions.
	The shipowner	The shipowner didn't prepare for documents related to emergency with the notice of TC.
	Transport Canada	TC didn't carefully choose the space material with the failure experience in the aviation industry.

If the shipowner of the vessel confirms with the HRO theory, they may notice those failures, namely accidents happening before and then make corresponding effective measures to avoid similar accidents. They can find the solutions when the problem of the vessel is still minor, which is easy to resolve. However, in this case, the shipowner of the vessel might not be HROs as the related personnel of the vessel didn’t learn valuable lessons from the past disasters. TSB has issued a few accidents before of passenger vessels or cruises for alerting similar accidents happening. For instance, one passenger vessel called Louis Jolliet grounded off Sainte-Petronille. The investigation also found that the crew members were not trained to act during emergency with written procedures, and TSB pointed that it was dangerous and existed hidden risks. With the past experience of failure, it showed that during emergency, efficient evacuation procedures were of extreme importance, while the shipowner still neglected the hidden risks, not preparing for evacuation plan, lifesaving plan, passenger safety briefing, as well as fire and boat drills.

Besides, as for this case, TC might not be extremely careful about the inspection, not considering the worst result. The lack of coolant resulting the overheating of the engine was the major cause of the fire explosion. As for the fire, the space material and the insulation as well caused harmful effect to some degree. It is noted that in the aviation circle, Mylar was no longer allowed to use after the Swissair Flight 111 accident, which could be a free lesson for the shipowner and TC as well to learn from and avoid use the insulation or take more care on the problem that this type of insulation may result in.

The action of the master and the deckhand after fire explosion primarily met with the requirements of the HRO theory. During the emergency happened, the master and deckhand didn't run away firstly, choosing to be committed to their duty. The master contacted the rescue team for evacuation, and local firefighters for extinguishing the fire. There also appeared some minor mistakes in this stage which have also been discussed about before. For instance, the deckhand didn't fully understand the instructions provided by the master during launching the life raft. Also, there didn't exist some written instructions for passengers to wear the lifejackets. All in all, despite the minor mistakes during emergency preparedness and life raft failure, the master, deckhand, rescue team as well as the firefighters all fulfilled their own responsibilities and held some professional capacity, successfully evacuating all the passengers.

Through analyzing, the master and deckhand, shipowner as well as TC were not totally HROs. They didn't expect the hidden risks from the past experience, and took some effective measures to avoid these risks. In terms of rescue, they had the ability to evacuate the passengers, avoiding the accident to turn more severe. From this side, they were HROs.

4.5. The fire explosion explained by McSween's safety model

In accordance with Marine Investigation Report M14C0156 made by TSB(2014), a fire started in the engine compartment during the period or shortly after an engine malfunction, while there showed no alarm for alerting the master for engine problem. In order to increase the speed to the normal speed, the master accelerated the throttle. Unfortunately, this resulted in the overheating of the engine, pushing it to totally break. Due to that, increasing heat and oil came into the compartment, bringing about beneficial conditions for the fire.

During the safety assessment, TSB firstly found the specific data of the vessel conditions and member. They collected the detailed data of the vessel such as the vessel particulars and the engine conditions as well as the specific timeline of the accident process. Besides, the data also presented the personnel allocation, passenger number and the owner of the vessel, providing us with a general idea about the background, which is of great significance for further investigation.

Except for gathering information from safety data, TSB also collected information from the report issued by Transport Canada(TC). It was found that through the inspection of 2013, the crew members of the vessel failed to submit the written evacuation plan. In 2014, there appeared more problems. Personnel related to the vessel still didn't prepare for the evacuation plan. Besides, the detailed written documents of life saving equipment and passenger safety briefing as well as the record of the fire and raft drills were all not be submitted for review. It was also found that the vessel had experienced renovation before.

In the safety assessment, TC provided one form for determining the minimum member on a vessel. TC took into account several elements such as the vessel type and its particulars, the situations of lifesaving and firefighting equipment, etc. Still not to satisfactory, when TSB investigators checked the evaluation form, finding that TC just ensured the minimum manning through the past experience, not evaluating again, for there appeared similar type of the passenger vessel before.

Through the information from safety data and the report, it indicated that the vessel existed risks especially in emergency for the detailed and specific procedures applicable to emergency hadn't been considered before. In terms of the safety management system, by reviewing the system of the vessel before, unfortunately, the company owned the vessel didn't set one structured safety management system, so the management system of the vessel was unclear and might be a bit confused.

Secondly, making interviews with the passengers, crew members and relative people is also an imperative way to further acquaint with the factual information of the accident. Through this step, TSB got the detailed information about the timeline of the vessel, when to prepare, when to start, when the fire started, etc, which has been shown in the below sections. Through talking with the master and deckhand, TSB got the situation of their certification and experience, making the preparation for further considering the risks and contributing causes. In addition, one passenger said that there had been no alarm to warn the master for engine breakage, and the passengers alerted the master at that time that the smoke had appeared around the engine compartment cover. Passengers also pointed that during the evacuation, only 2 of the 3 life rafts were usable, depending on the life raft of another passenger ship for rescue.

It is recommended by McSween that observing the meeting, training or drill can help to get more familiar with the safety performance of the working place. For TSB, they didn't have the chance to observe their actual training or drill, but they investigated the detailed information about emergency situations. Through occurrence of the fire, TSB found that the crew hadn’t carried out fire or life raft drills before, and TC hadn’t pointed out the risk before in the annual inspection report. Besides, there had no written emergency procedures on the vessel. All of these posed great risks to safety.

TSB had already analyzed the basic background of the accident and the injuries of the accident in the preliminary investigations for further reference. Through thorough investigations, TSB found the list of safety practices from the causes and contributing factors.

As for the causes and contributing factors, TSB concluded that it faced 3 periods.

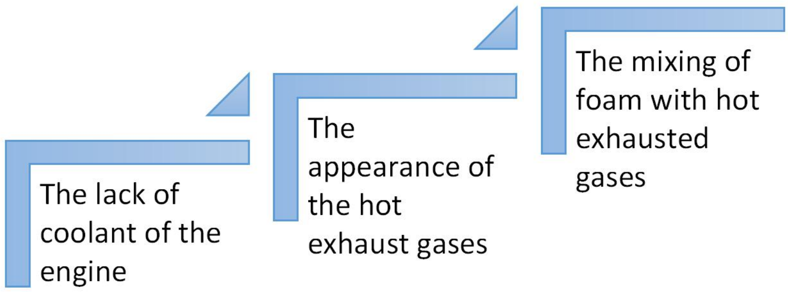

Figure 7-The contributing factors of La Releve II accident

1.The lack of coolant of the engine made the engine overheated, resulting in the crack.

2.The damaged hose together with the crack brought about the hot exhaust gases, breaking the insulation and merging into the foam.

3.As the foam turned humid in oil, it mixed with the hot exhausted gases again, the fire then started.

In addition, TSB also published a Watchlist pointing risks, appealing the relative parties to address these problems for further improvement, and the detailed information can be found in the website of TSB. Through investigation, some risks still appeared which may increase the probability for the accident happening again, so TSB identified the list about the risks, which can be shown in table 5.

Table 5-Hidden risks shown in the La Releve II accident

Item	Inappropriate behaviors	Risks
1	The lack of written emergency procedures	Failing to implement evacuation effectively
2	No guided rules for TC to implement inspection	Accelerating substandard vessels receiving certificate
3	The lack of safety requirements in SIRS	
4	Ensuring the minimum safe manning through experience	Increasing the probability of accidents
5	The lack of formal written safety procedures	

1.Through investigation, the crew members didn't keep written emergency procedures, increasing the probability of not fulfilling their corresponding roles efficiently and effectively in an emergency.

The fact showed that although the deckhand and the master took actions after the fire started, the actions were not taken in the appropriate order.

During the emergency, the crew members didn't alert the passengers in advance for noticing the accident would happen and they should prepare for evacuation.

However, it was the passengers themselves that found the smoke and then conveyed the information to the master.

During the stage of preparation for evacuation, the passengers wore the life vests by themselves without assistance or the written instructions.

As for the life rafts, they were not launched immediately after the fire started, and the deckhand was not totally sure about the instructions delivered by the master.

Last but not least, when boarding the life raft, the passengers boarded from both sides of the vessel, but it is not appropriate for people to board from the port side.

All of these behaviors and performance showed that without written emergency procedures and regular drills, the crew members would be not quite familiar with the process, which might be dangerous and increased the severity of the accident.

2. TSB found that there was no specific rule for Transport Canada to investigate the deficiencies of the vessel, accelerating the happening of the accident.

It is easy to understand in this part. As for the inspector, he or she needs to make plan approval according to the rules. And through rules, they can conclude what is the minor and what is the big mistake. In addition, the rules may also determine that to what extent the inspectors may have the right to issue or withdraw the certificate, and on what conditions they can extend the certificate for the vessel. The situation is similar from the side of on-site surveyors. The regular inspection is necessary for following up the deficiencies provided before by the inspectors to reduce safety risks. And if the problems have been found, while no subsequent actions or if there appears big risks in the safety, the certificate still issued, the inspections are meaningless, for they lack the roles for safety advancement.

3. The Ship Inspection Reporting System (SIRS) database did not include all the safety requirements, increasing the risk of still receiving the certification of the vessel despite of a variety of deficiencies.

As for the database, it should be confirmed that the information is in the wide range and always true for checking, which can be considered as the guideline for inspectors.

4. TSB found that the minimum safe manning only referred to the precedent, not taking into account the actual conditions. And the number of life rafts was higher than that of crew members, so there might lack sufficient person during emergency.

Although the minimum manning was achieved through the same type of the vessel, a brand-new evaluation still required. The same type of vessel may still exists small differences, so only depending on the past experience may not be rational. More life rafts than crew members

may cause some confusions. Some passengers may try to launch the life rafts due to worry, but they are not familiar with the usage of the life raft.

5. It was found that the vessel operators did not hold formal written safety procedures, which might increase the hidden hazards.

The above analysis has identified the LA RELEVE II accident using the model upheld by McSween and mainly found 3 consecutive steps that contributed to the accident; 5 risks for further precaution. The results indicate that not only the direct contributing factors can lead to the accident but also those risks can result in the next disaster. To prevent similar accidents from occurring, all the relevant parties are obliged to endeavor to increase information flow, improve investigation and management, while not focusing on the superficial causes to the accident. One organization or punishing persons only cannot prevent the similar accidents happening as LA RELEVE II.

The analysis confirms with the model by McSween, focusing on the combination of unsafe behaviors and conditions, which will be more efficient and effective than only considering one perspective. As applying for McSween's model to the accident of LA RELEVE II, it shows that the model can be applied for various circles, not only in the office. Using this model helps us to allocate the data efficiently so as to prevent other similar accidents.

5. Case analysis II-Grounding of Maersk Garonne

5.1. Introduction of the vessel and the accident

5.1.1. Brief description of the Maersk Garonne vessel

Maersk Garonne was owned by Maersk, flagged in Denmark and classed in Bureau Veritas(BV). During the occurrence of grounding, the vessel was on a regular cargo delivery service between Asia and Australia. The vessel was equipped with navigational equipment including radars, electronic chart display and information system(ECDIS) and so on (ATSB Transport Safety Report, 2015).

Besides, detailed information of the vessel can be shown as below table 6.

Table 6-The detailed information about Maersk Garonne

Name of vessel	Maersk Garonne
IMO number	9235579
Call sign	OUTK2
Flag	Denmark
Classification society	Bureau Veritas
Ship type	Fully cellular container ship
Builder	Hyundai Heavy Industries Company- Ulsan, Korea
Year Built	2003
Owner(s)	A.P. Moller- Maersk,Denmark
Manager	Maersk Line Ship Management, Singapore
Gross tonnage	50,757
Deadweight(summer)	61,608t(4,318TEU)

Summer draught	13.522m
Length overall	292.13m
Moulded breadth	32.25m
Moulded depth	21.7m
Main engine(s)	Hyundai MAN B&W 10K90MC-C
Total power	42,100 kw,104 rpm(MCR)
Speed	24.2 knots

Source: ATSB Transport Safety Report, 2015.

5.1.2. Brief description of the Maersk Garonne accident

On 28th February 2015, the container vessel Maersk Garonne suffered grounding when the vessel arrived Western Australia from Singapore. As reported, around 04:35, as the vessel approached the entrance channel to wait for the harbor tugs to assist berthing. After communication, the harbor tugs were late than the vessel, and then the pilot decided to delay the vessel entering the entrance channel, leading to the deviation of the vessel, then resulting in grounding. With the assistance of the relief pilot and more tugs, Maersk Garonne succeeded in re-floating the vessel at 8:24(ATSB Transport Safety Report, 2015).

After thorough inspection taken by Australian Transport Safety Bureau(ATSB) , fortunately, no damage was made to the main engine as well as the whole vessel except for some slight scarping.Its main engine reached satisfaction that afternoon, and the vessel successfully berthed in the evening of March 1st.

ATSB concluded that the initial event of the grounding was due to faster speed than the tugs, and then the wrong decision of the pilot about delaying entering the channel became the main cause of grounding.

As for the specific timeline of the accident, it can be presented as below.

At 4:00, a harbour pilot boarded Maersk Garonne for entering the entrance channel.

From 4:00 to 4:35, the vessel progressing toward the entrance channel with the instruction of the pilot.

At 4:43, the pilot decided to delay the vessel's progress toward the entrance channel.

At 4:48, the vessel was outside the entrance channel, then grounding in the shallow water.

As for the analysis of the first case, I have applied four models to that, and in the next chapter, I will choose three models, energy-barrier model, the high reliability organizations model(HRO) as well as McSween's safety model to analyze this accident. In my opinion, these three models are more suitable for this accident, and more representative for analyzing the accident.

5.2. The grounding explained by the energy-barrier model

Table 7-The items related to energy barriers in Maersk Garonne accident

Barrier function	Sub-function	Relative personnel
Prevent grounding	Improve employee's quality	Employees
		The company of the employees
		Crew members
		Pilot
		Shipowner
	BRM improvement	Personnel managing the pilot
Prevent grounding	Adequate use of pilotage or navigational units	Crew members
		Pilot
	Communication	Pilot

	improvement	Vessel crew members
		Tug master

As for this case, “delay entry” could be considered as the beginning incident, and “grounding” was the perilous event. Hence, how to prevent grounding was the critical issue to this case. In other words, “prevent grounding” was the barrier function of this case.

In terms of barrier sub-functions, in my opinion, to begin with, “ improve employee’s quality” can be seen as one barrier sub-function. As for the pilot, he firstly required too fast speed of the vessel to enter the channel, and when he realized that the vessel was faster than the tugs more than 3 minutes, he chose to delay the ship’s entry. Besides, the pilot’s overall instructions was not prevented by any staff on the vessel. From this side, the pilot as well as the staff members on the vessel all need to improve the quality of expertise to make more appropriate decisions.

The second barrier sub-function can be regarded as “adequate use of pilotage or navigational units”. In this case, the pilot didn’t carry a portable pilotage unit, meaning that the pilot didn’t hold written procedures for instruction, so he couldn’t carry out appropriate measures to monitor the progress of the vessel for entering the channel.

Then, it came to the improvement of bridge resource management (BRM), which can also be one barrier sub-function. As for the BRM, which can be seen as the capacity of using and coordinating various things such as resources, people and equipment. However, in this case, BRM wasn’t carried out well.

Last but not least, the improvement of communication should also be another barrier sub-function. In this case, the vessel was faster than the tugs at least 3 minutes, which was the initial incident of the grounding. In other words, it showed that, the communication between the pilot and the tug master should be improved so as to coordinate the speed of vessel as well as the tug.

As explained in the first case, energy-barrier model can be applied to analyze the cause and result of one case. It was also obvious in this case that with the failure of these barrier sub-functions, the grounding happened. Furthermore, strengthening these barrier sub-functions including “improve employee’s quality”, “adequate use of pilotage or navigational units”, “improve bridge resource management (BRM)” and “improve communication” can lay the solid foundation for further avoiding similar accidents occurring.

5.3. The grounding explained by high reliability organizations (HRO) model

If the High Reliability Organizations (HRO) theory is applied to analyze the grounding event, the characteristics of the theory should be focused on. Also like the same case, those people related to the accident can be analyzed thoroughly. Some of their actions were appropriate, while some were not. When applying this model to the accident, in my thesis, I always divide the behaviors into two stages, how to prevent and then how to control the accident.

Table 8-HRO analysis in Maersk Garonne accident

	Relative personnel	Behaviors
Confirming with HRO	The captain and crew members(partly)	Conducting thorough hull inspection after refloating of the vessel
	The pilot(partly)	Contacting VTSO for rescue
Not confirming with HRO	The captain and crew members(partly)	Not alerting inappropriate actions of the pilot
	The pilot(partly)	Not confirming with the total requirements of a pilot

To begin with, if the pilot and the staff members on the vessel were HROs, they should have the ability to learn lessons or some effective solutions from past experience as the grounding frequently happened in the past. Still, the pilot didn’t completely confirm with the standard requirements of a pilot. For instance, the pilot didn’t take a portable pilotage unit so that he made inappropriate decisions, delay to enter the channel, resulting in grounding eventually. At the same time, the master as well as the employees didn’t challenge the instructions provided by the pilot through the whole pilotage period.

On the other hand, after grounding, I suppose that the captain, crew members and the pilot as well were HROs. They were committed to their own jobs, shouldering their own responsibilities. They did take some corresponding actions to relieve the problem. After unsuccessful attempts by the pilot to refloat the vessel, the pilot contacted the duty vessel traffic service officer (VTSO) for providing another tug and one relief pilot for assistance. When the relief pilot boarded the vessel, the original pilot still on board to carry out assistance. At that time, the staff members took their responsibility to make hull inspection to find out whether there appeared some problems. After that, the ballast water in the forward tank was discharged for assisting re-floating. At the same time, two tugs also arrived for assistance. At 8:24, Maersk Garonne successfully re-floated with the vessel’s engine and thrusters. Under the requirement of VTSO, the vessel was taken to Gage Roads for thorough inspections. On the next morning, the vessel was taken underwater inspection, while no damage was found only with minor paint scraping. In that afternoon, after trial, main engine confirmed with requirement, safely berthing in Fremantle that evening. On 3rd March, after uploading the cargos, the vessel left the port (ATSB Transport Safety Report,2015).

The high reliability organization theory (HRO) emphasizes on explaining why severe accidents not frequently happen. In my opinion, if related parties all confirm with the requirements of HRO, they may have the ability to make precautions and take effective measures after every minor failure. HRO is conducive to analyze the accidents chose by me, but it may not quite suitable for analyzing those accidents causing severe damages and fatalities.

5.4. The grounding explained by McSween's safety model

According to ATSB Transport Safety Report, Maersk Garonne grounded due to the inappropriate actions by the pilot, which has been introduced already. Although it didn't cause severe results or it couldn't result in severe fatalities like passenger vessels, safety should still be the first priority in the maritime industry, also for container vessels. As is known to all, the cost of manufacturing and maintenance the vessel is very high. Meanwhile, the installation of onboard equipment costs high price. Hence, after the accident, even grounding, it may still make damages to the vessel to some degree.

When applying McSween's safety model to the grounding incident, the first step is about safety assessment. In this case, if we evaluate whether the investigations taken by ATSB confirms with the requirements of McSween's safety model, the safety assessment may appear after the accident for ATSB mainly involve in after the accident for investigation. Also, as the foundation, ATSB, like previous TSB found out the detailed information about the vessel such as the ship parameter, IMO No. and the shipowner.

To better make safety assessment about, ATSB got familiar with relevant information concerned with the voyage history for further confirmation about contributing factors of the accident. Through investigation, after the pilot arrived at the bride, the pilot and the master exchanged information while lacking some key points. They didn't agree with the vessel speed as well as the requirement of the main engine as the vessel sail toward the channel. They didn't have a clear plan about the altered course if some changes happen. Also, they didn't discuss about the emergency plans for rescue during accident. Besides, the pilot as well as the master had no idea about making timely and effective communication with VTS and tugs to share about the current process.

As for the passage plan, it can be regarded as the understanding of the bridge members about the involvement of the pilots. The ship's SMS procedures ruled that for some items, they need to be specifically marked in the chart of the passage plan, and a few of items should be included in the passage plan including emergency plans, safe speed, etc. However, as for Maersk Garonne, only the requirement of the safe speed and appropriate speed change were covered in the passage plan, indicating that the bridge team hoped the pilot to cover the missing items ruled in the SMS procedures.

Next, McSween also points that making interviews with the relative personnel is also of extreme significance for further thorough understanding about the background and the detailed information about the incident. ATSB followed this step, interviewing the pilot to get familiar with his certification and the information about the grounding. According to interview, the pilot of the vessel was showed with rich experience, and he was also an experienced vessel master, so he was greatly familiar with the ship's performance, clearly knowing about different kinds of vessels at various speed may affect the ship's progress. The pilot recognized that the decision to alter the course to wait for the tug was not an advisable idea, but he did that to overcome the previous too-fast speed mistake. From this perspective, it shows that experienced personnel with certification may also make mistake, so emergency planning is critical when facing risks to guide the pilot avoid the accident. In this step, ATSB also collected the exact timeline of the process of the vessel including departure time, the boarding time of the pilot, the grounding time, rescue time, etc.

Besides, as for observing, McSween upheld to observe the company's situations working situations such as their meetings and training for better acquaintance about their safety performance, which was also discussed in the previous chapter. In this case, ATSB observed the situations through video recording the whole process of bridge members and the pilot. There were several points not quite satisfactory. For instance, there appeared no contingency planning between the pilot and bridge members. When facing the situation of the delay of the tug, the pilot as well as the bridge team all didn't take instant reactions. In my opinion, grounding is a common phenomenon, so it is necessary for these relative personnel to implement emergency plans for avoiding these risks. During pilotage, sometimes one observer appears for observing the actions of the pilot, while that exists risk for distraction of the pilot. In this case, through the bridge recording, there was one student observer on the vessel during pilotage, while the pilot and the observer kept conversation with the observing, interrupting the communication between the pilot and the bridge members.

McSeween also emphasized on the importance of management technique. In this case, ATSB also made surveys on the vessel's management technique. As for safe navigation, one management technique is commonly accepted by the industry, which is called bridge resource management(BRM), representing the comprehensive utilization and coordination of various kinds of resources for improving safety and efficiency. However, in this case, many items in BRM were not implemented by the crew members. In detail, error management is extremely vital in BRM, which is composed of two elements, indicating how to reduce the occurrence of the errors and how to limit the severe outcomes. In terms of Maersk Garonne, neither the bridge team members nor the pilot carefully checked the vessel's progress to implement error management. For instance, not every member of the bridge team was involved in the pilotage, not all bridge equipment was used for monitoring the progress of the vessel, and no appraisal was taken in terms of the position of the tugs. In this case, no effective communication was taken. As for the pilot, he didn't discuss with the team members about his plan for delaying entering the channel, and meanwhile, no one challenged the pilot, which breached the principles of BRM.

Besides, as for the management system, safety management systems (SMS) were implemented by various parties ensuring safe navigation of the vessel including the shipowner of the vessel, Maersk, Fremantle pilots and Fremantle ports. As for this management system, each one covers information related to BRM, passage planning, as well as the exchange information between the master and pilot.

In McSween's model, not only preliminary investigation should be focused on, thorough investigation should also be paid more attention to. In the report of ATSB(2016), the party analyzed the direct and hidden reasons of grounding in detail. Through the preliminary analysis, ATSB got familiar with the whole process of the accident, conducive to analyze the contributing factors of grounding. To begin with, the initial event was that Maersk Garonne arrived the entrance channel earlier than the tugs. From this perspective, the first mistake was that the vessel's speed was too fast, exceeding that of the ship's passage plan speed and the port's recommended speed. Due to that, the pilot's decision to delay entering the channel became the main cause leading to the grounding. Then, ATSB specifically analyzed the hidden reasons causing the grounding. Why the grounding happened? Why the pilot took that inappropriate decision? To answer these questions, we found that the pilot didn't carry a portable pilotage unit for instruction, so he didn't make appropriate decisions when facing emergency. In this part, the bridge members also had the responsibility to challenge the pilot for pointing that the speed for navigation was too fast, and the delay to enter was not appropriate. For theses sides, it affected a few problems in indirect sources. BRM was not adequately implemented on the vessel, Fremantle Pilots' procedures didn't focus on emergency plans, and the communication between the vessel and the tugs was ineffective, which have also discussed about in the below sections in detail.

In general, McSween's model was mostly applied to investigate and analyze the case by ATSB. ATSB carried out preliminary and detailed investigations on the grounding, meeting with the recommendation of the detailed safety assessment by McSween. When implementing investigation, ATSB also carefully observed the actions through bridge recordings for detailed information. As stated by McSween, effective observation is critical. How to present the observation is also of great significance for transparency and further improvement. Hence, ATSB compiled the report from different aspects, and analyzed the contributing factors of the accident for avoiding similar accidents. ATSB also focused on the management technique, which was also advocated by McSween to emphasize on. Finally, how to maintain safety is the last step appearing in the McSween's model. After investigation, ATSB found out the problems affecting the grounding from direct and indirect sides, pointing out the measures to overcome these problems so as to maintain and strengthen safety.

6. Discussions on applying the models to analyze accidents

The below table 9 provides us a fundamental idea about the assessment of these theories for analyzing various accidents. Through applying these four models to two cases, we can get more thorough conclusions on these four theories, laying solid foundations for further application so as to more comprehensively analyzing the various accidents and avoid them occurring again.

Table 9-Assessment of four theories

	Whether or not suitable for analyzing the accident		
Theory/Model	Applied to Case I	Applied to Case II	Assessment
Energy barrier model	Yes	Yes	High availability, and the model can be used to analyze different kinds of accidents.
MMD model	Yes	No	1.Only focusing on the lack of information exchange among people. 2.Failing to interpret unsuccessful readjustment behaviors during rescue.
HRO model	Yes	Yes	Only for interpreting not quite severe accidents with slight deterioration or casualties.
McSween's model	Partly	Partly	Only for providing detailed structure for improving safety, not for process analysis.

Each model focuses on different perspectives when analyzing the accident. And not all the models regarding safety can be use to analyze each kind of accident. I suppose that one case only are not quite representative, not enough for comparing the availability for different kinds of model applying to the accident. Hence, I choose two famous accidents with different adverse outcomes brought from different contributing factors.

When applying the energy-barrier to accident analysis, it is remarkable that both accidents can be analyzed by this model, and this model helps to find causes resulting in the disaster from the root. The energy-barrier model describes the accident through two sides, from proactive and reactive barriers, while in the two cases introduced in the thesis, proactive barriers prevail, always helping to directly solving the problem. Through analyzing, it can be found that the ignoring of those effective energy barriers did threaten safety, and lead to the accident. Hence, this model is extremely extensive for interpreting different kinds of accidents. How to effectively use these proactive barriers should be the first priority for preventing the occurrence of the accident, while the failure of using the barrier sub-functions can lead to the accident, which may also cause severe damages and fatalities.

When it comes to MMD theory, the theory exists limitation as the theory focuses on those accidents resulted from the lack of communication among people about those hidden risks. However, not all the accidents are caused by this reason, so it shows less availability compared to the energy-barrier model. Take these two accidents as an example, only one of them can be analyzed by MMD model. And if the accident really exists the problem of lacking information exchange, the model still exists another shortage. MMD theory upholds that during rescue period, people may adjust their minds and actions to mitigate the problems, and for the case I choose, it is suitable, while some accidents also appear that crew members don’t take any effective measures for rescuing and even evacuate first. For those accidents, those people don’t revert their mind to improve safety, and MMD theory is not conducive to resolve the problem. Hence, those accidents may not be effectively avoided by applying MMD theory due to the shortage of this part in MMD theory.

As for the HRO theory, it indicates that people should pay more attention to the past accidents so as to make effective precautions to avoid similar accidents occurring. This theory is suitable for analyzing those minor accidents. If the shipowner confirms with the HRO theory, the accident may rarely happen, or if the accident really occurs due to some other reasons, relative personnel should have the capacity to control the hazard. In this part, HRO theory is effective, while overlooking the overall industry, although severe accidents have reduced in the recent years, some of them still happen. Hence, how to analyze these kinds of accidents is critical. From this perspective, HRO fails to resolve the problem for severe accidents, existing limitation.

McSween’s model shows another perspective to analyze the accident. It is different compared with the following ones, this model doesn’t emphasize on the direct causes or the whole accident process analysis. McSween’s model devotes to construct a layered structure for instructing how to keep safety from the beginning to the end linkage, which pass through before sailing including the daily safety assessment to various linkages like daily operation, written procedure, emergency measures, etc. The model is always popular among various industries, combining unsafe conditions with behaviors. I suppose that this is the advantage of the model, while it can’t be applied for analyzing the middle linkage of the accident, but it can be regarded as one instructive document for checking each linkage of the safety processes for finding out the problems and then improving them.

In my opinion, all of these models are effective and helpful. They are not similar, analyzing the accident from different perspectives, but they are not contradictory. Some models may exist limitation, but it doesn't mean that they are valueless. To avoid limitation, the application of different kinds of models may achieve the analysis more comprehensively, thus making further improvements efficiently and effectively. It is noteworthy that the ultimate goal of these models is the same, reducing accidents and improving safety. Hence, the combination of these models can be the instruction for safety improvement.

7. Conclusion

Maintaining safety is gradually emphasized on by increasing people in different areas. Whatever we do, safety should always be put in the first priority. In terms of the maritime industry, it's also the same. A few of conventions and regulations were launched before such as SOLAS for protecting the safety of vessel crew members.

To improve safety, the first step is to be clear about the frequently happening accidents through carefully analyzing. In this step, we can make advantage of some models such as HRO theory, MMD theory, and energy-barrier theory. Recognizing the problems is critical, then how to prevent and maintain safety is also as the same importance. At this time, some models are conducive such as energy-barrier model, McSween's model, etc.

In conclusion, with the development of the whole society, safety should always be paid attention to and take effective measures, which requires the whole society to make corresponding efforts.

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