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The safety management and analysis of containers carrying dangerous goods by sea

Chao Ma

WORLD MARITIME UNIVERSITY

Dalian, China

The Safety Management and Analysis of Containers Carrying Dangerous Goods by Sea

By MaChao

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DECLARATION

I certify that all the material in this research paper 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 research paper reflect my own personal views, and are not necessarily endorsed by the University.

Signature: Machao
马超

Date: July 12, 2013

Supervised by: Zhang Shuohui
Professor
Dalian Maritime University

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ABSTRACT

Title of research paper: **The Safety Management and Analysis of Containers Carrying Dangerous Goods by Sea**

Degree: **MSc**

With the rapid development of the chemical industry and container transportation recent years, the quantity of dangerous goods transported by sea has grown quickly year by year. Due to a series of advantages such as less cargo loss, high safety factor, low-risk, less environmental pollution and high economic benefits, more and more dangerous goods are carried in containers in the international marine transportation, which makes the number of containers carrying dangerous goods by sea increase rapidly. Besides, the class of dangerous goods carried in containers covers all 9 classes up to now, and types of dangerous goods carried in containers by sea are still growing now.

Although there is a great development of containers carrying dangerous goods by sea, the incidents of containers carrying dangerous goods are increasing recent years, involving the packing of containers, the stowage and segregation in the ship, undeclared dangerous goods and the emergent measures when accidents happen, which threatens the safety of ships, crew, goods and marine environment seriously. Nowadays, how to strengthen the safety management of containers carrying dangerous goods by sea has become the issue of common concern in the international maritime industry.

There are four chapters in the thesis. The first chapter is the introduction to the container carrying dangerous goods by sea, including the main information of dangerous goods and the current situation of containers carrying dangerous goods. The second chapter is the analysis of risk sources for the container carrying dangerous

goods by sea, which covers the research of the packing of containers, the stowage and segregation in the ship, undeclared dangerous goods and the emergent measures. The third chapter is the application of the formal safety assessment (FSA) in the container carrying dangerous goods by sea. Lastly, the fourth chapter is the conclusion of the thesis.

Keywords:

The container carrying dangerous goods by sea; Safety management; Risk source; Formal Safety Assessment (FSA)

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LIST OF ABBREVIATIONS

CSC	International Container Safety Convention
DMU	Dalian Maritime University
FSA	Formal Safety Assessment
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
LCL	Less Than Container Load
MARPOL	International Convention for the Prevention of Pollution from Ships
MSEM	Maritime Safety and Environmental Management
PSC	Port State Control
SOLAS	International Convention for the Safety of Life at Sea

Chapter 1. Introduction to containers carrying dangerous goods by sea

1.1 Introduction to the transportation of dangerous goods by sea

Dangerous goods are those cargoes which have the characteristic of explosive, flammable, toxic, corrosive and radioactive, and they are likely to cause personal injury, property damage or environmental pollution in the process of carrying, stevedoring and storing. With the development of modern industry, the quantity of containers carrying dangerous goods has become larger and larger. Compared to general goods, there is much more risk and much higher technical operations requirements for dangerous goods, which have offered new challenges to the maritime industry.

Generally, dangerous goods are from the following aspects: the material from chapter VII of SOLAS1974 and the substances from the Annex I, II and III of MARPOL73/78. As is known to us, the classification of dangerous goods is based on the relevant regulations of SOLAS 1974 and MARPOL 73/78. Besides, the categories of dangerous goods are listed in section 2, Part A, Chapter VII of SOLAS 1974, and some categories are further subdivided by the International Maritime Dangerous Goods Code (IMDG). The Annex III of MARPOL 73/38 identifies environmentally harmful substances, which provides the criteria for marine pollutants.

The Resolution 56 of SOLAS Conference established the Working Group Transport of Dangerous Goods to draft the IMDG code in 1960. Besides, the IMDG code was passed by the Resolution 81st of the Fourth International Maritime Organization Diplomatic Conference, on September 27, 1965. Generally, the IMDG code is revised every two years; the 31st amendments of IMDG code was entered into effect on January 1, 2004, and it was to be the mandatory rules since this amendment.

IMDG Code divides dangerous goods into 9 class, as the following

Class 1	Explosives
Class 2	Gases
Class 3	Flammable liquids
Class 4	Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases
Class 5	Oxidizing substances and organic peroxides
Class 6	Toxic and infectious substances
Class 7	Radioactive material
Class 8	Corrosive substances
Class 9	Miscellaneous dangerous substances and articles

Table 1.1 The 9 class of dangerous goods Resources: IMDG Code

1.2 The current situation of containers transported by sea

The international maritime transportation container is a great innovation compared with the traditional mode of transportation since the 20th century. It is also an important product during the modernization of transportation. For half a century, with the rapid increase of the quantity and quality of international trade, the container transportation in the international shipping has also changed greatly and turned to be more mature gradually.

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The rapid development of maritime containers has changed many shortcomings of traditional loading and charging ways, such as more handling links, more labor-intensive, inefficient loading and discharging, long shipping cycles and so on. Taking the time of stevedoring as an example, it takes one hour to load or discharge cargo of 35 tons for general cargo ships, but the efficiency of container ships is improved greatly because of the high mechanization. It only took 7.5 hours to load and charge 5182 TEU containers of MV "CSCL Zeebrugge" at Shanghai port on May

19, 2007, which means that 690.93 TEU containers were loaded or charged hourly. (Zhuang, 2008). In addition, the time for container ships staying at ports has reduced a lot because the stevedoring efficiency of containers is relatively higher and it is affected less by the climate or weather, which is beneficial to shorten the voyage time, thereby increasing the transportation capability of container ships.

The transportation efficiency of containers are improved greatly, which can be described as follows:

a. Simplifying the packaging, and saving the cost of packaging

To avoid damage to goods during the transportation, there must be robust packaging. Meanwhile, containers are rugged and sealed, so the container itself is an excellent package and the cargo transported in the container is beneficial to simplify the packaging and save the packaging cost.

b. Reducing damage of cargo and improving the quality of transportation

As the container itself is a sturdy sealed unit, it is not necessary to open the container many times after the cargo loading in the container and lead sealed. It is unlikely for the cargo in the container to be damaged in long-distance transportation. In addition, the transportation of containers can reduce the risk of cargo getting damaged,wet,dirty or being stolen.

c. Reducing operating costs and transportation costs

Generally, the transportation of containers is hardly affected by terrible weather, which can shorten the berthing time of ships at ports. Meanwhile, the stevedoring time is shortened because of the high stevedoring efficiency. On the one hand, it improves the navigation rate and reduces the shipping cost for shipping companies. On the other hand, it improves the capacity of berth using for ports, thereby enhancing cargo throughput of ports and increasing their revenue. (Li, 2007).

1.3 The situation of containers carrying dangerous goods by sea

As is known to us, the container transportation is the most important and active mode of the world shipping nowadays. The throughput of containers in global ports exceeded 615 million TEU in 2012, while the throughput of containers in Chinese ports reached the number of 140 million TEU at the same year. With the development of world shipping, the number of containers carrying dangerous goods has increased year by year.

Taking the port T of China as an example, the number of vessels carrying dangerous goods containers in port T was 9803,9917,11053 in the years of 2010, 2011, 2012 respectively, and the quantity of containers carrying dangerous goods in port T was 145,273, 186,136, 204,124 TEU in 2010, 2011, 2012 severally. The numbers are shown in Figure 1.3.

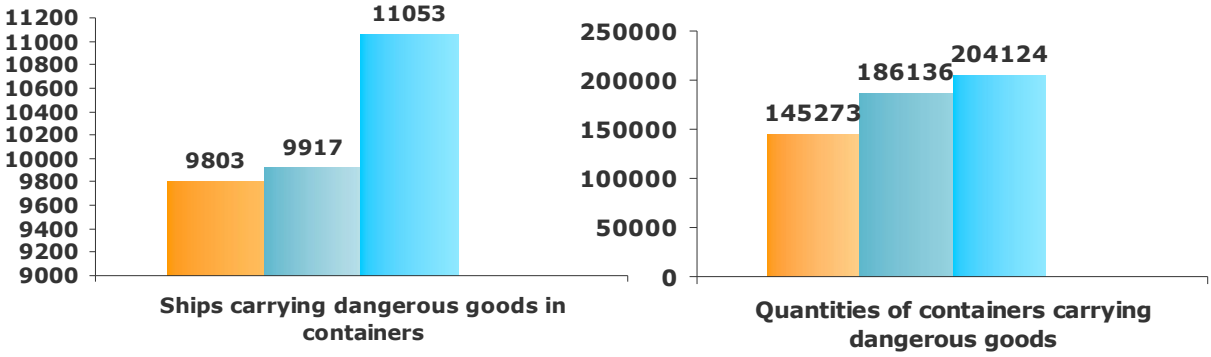

Figure 1.3 The condition of containers in port T Resources: T Maritime Safety Administration

1.4 The characteristics of the transportation of containers carrying dangerous goods by sea

The biggest advantage for containerizing dangerous goods is that dangerous goods with the characteristics of flammablity, explosiveness, toxicity, corrosiveness and radioactivity can be loaded in an airtight and sealed container, which greatly reduces the harmful level of dangerous goods for the ships, crew, ports and other goods, and

its safety condition has been improved a lot. As a result, more and more dangerous goods are transported in containers because the dangerous goods are not likely to be damaged or sprinkled in the container. Besides, the process of transportation is so quick and simple that the time of loading and discharging can be reduced a lot.

There is no doubt that the container is safe enough if its packaging is intact, the mark is clear and correct, the stowage and segregation of cargo in containers are reasonable during the transportation. However, the special characteristic of container transportation is that the cargo in the container can not be checked after dangerous goods are loaded and sealed. (Cai & Song, 2007). As a result, accidents caused by dangerous goods reaction would happen if the packing of dangerous goods is broken or other reasons. In other words, there is great risk during the transportation of dangerous goods; a serious accident could happen if the containers carrying dangerous goods are disposed improperly, which will cause huge losses for the crew, ships, cargoes and environmental resources.

1.5 The risk of containers carrying dangerous goods by sea

Accidents for containers carrying dangerous goods are very likely to happen during the storage and transportation because of the improper operation. Meanwhile, if an accident happens, it will seriously threaten lives of crew, damage the safe navigation of ships and pollute the marine environment.

There were so many accidents of containers carrying dangerous goods in the maritime history. The Liberian container vessel "HANJIN PENNSYLVINIA" occurred the calcium hypochlorite ($Ca(ClO)_2$) explosion on November 11, 2002. The vessel which could carry more than 4,000 TEU had finished her maiden voyage before the accident. When sailing on the waters near Singapore, 122 miles from the southeast of Colombo, the vessel suddenly caught fire because of the explosion. The fire had

resulted in the damage of most goods, and the loss reached more than a billion dollars. The picture of accident is shown as Figure 1.5.

Figure 1.5 The accident of "HANJIN PENNSYLVINIA" Resource: Investigation Report of "HANJIN PENNSYLVINIA"

The Singapore vessel "HAI AN" exploded suddenly in Durban port when waiting for berthing on October 11, 2003. A crew member died in the accident because the fire could not be controlled in time. According to the accident investigation, the explosion was caused by a container loaded with calcium hypochlorite ($Ca(ClO)_2$). The consigner of the container concealed the true name and character of the cargo to the carrier. What is more important, the container was stowed in the position close to ship engines by the crew who were unaware of the truth. The heat from engines was transmitted to the container with calcium hypochlorite in the process of transportation, and calcium hypochlorite finally reached to the critical point of decomposition reaction, which caused the explosion and fire.

Chapter 2. The risk source analysis for transportation of containers carrying dangerous goods by sea

2.1 The characteristic of dangerous goods

Due to its explosive, flammable, toxic, radioactive and other characteristics, the dangerous goods itself is a risk resource. According to the provisions of IMDG code, the dangerous goods can be divided into nine class. To recognize the potential hazard of the dangerous good, it is necessary to study its variety, including its flash point, melting point, boiling point, ignition point, the explosion limit, the transport index, toxicity and hazard classification, etc.

Some substances and materials have the highest priority in different class of dangerous goods, such as the explosives of Class 1, the gas of Class 2, the liquid desensitized explosives of Class 3, the pyrophoric substance of Class 4.2, the substances of Class 5.2, the toxic substances of steam inhalation of Class 6.1, the infectious substances of Class 6.2, the radioactive substances of Class 7. In addition, precedence of hazards is shown in the IMDG code. Besides the main risk, the subsidiary risk, the potential threat for the marine environment and the limited quantity of dangerous goods are the important basis for recognizing the hazard degree of dangerous goods. If the quality of dangerous goods does not comply with the regulations of IMDG code, the risk of dangerous goods will become much bigger. For example, the stabilizer should be needed to add during the transportation, so that the dangerous level will be in connection with the content of stabilizer. In practice, lots of accidents happened because the real information of dangerous goods is concealed by the shipper or agent.

2.2 The risk of packing in the container

The packing condition of containers carrying dangerous goods is an important aspect

which can not be ignored for in the process of transportation. As is known to us, dangerous goods are always subject to vibration, shock, changes of temperature and humidity and other environmental factors. As a result, accidents such as leakage, fire or explosion will occur if there is something wrong with the packing of dangerous goods in containers. The writer found that the condition of containers which were not packed according to the regulations of IMDG code is still not optimistic. Taking port T of China as an example, the situation for the packing of containers carrying dangerous goods inspected by maritime administration in 2010, 2011, 2012 is shown in Figure 2.2,

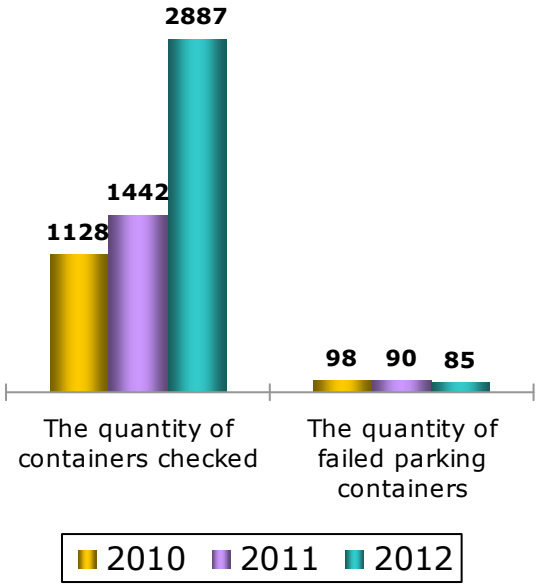

Figure 2.2 The quantity of containers checked in Port T Resources:T MSA

2.2.1 The hazard of packing in containers against standards

The problems of not standardized packing for containers carrying dangerous goods have seriously threatened the safety navigation of vessels, the container freight station and lives of crew. In recent years, accidents caused by not standardized packing of containers carrying dangerous goods happen frequently.

The MV "LT UTILE" which belonged to the Italian cruise company caught fire while anchoring at Shenzhen port in August, 2003. According to the descriptions of the

crew, the reason for the fire was the container stowed in BAY311482 in the vessel. During the inspection, maritime officers found that the cargo "Methyl Ethyl Ketonec" loaded in the container was not fixed well enough by workers, which directly resulted in the accident. Since "Methyl Ethyl Ketonec" decomposes at normal temperature, air holes must be left on the openings of drums. When the drum was tilted or toppled over, the dilution solvent will block the holes, but the decomposition reaction still continued in the drum. As a result, the pressure would grow quickly and the speed of liquid leakage would accelerate. Once it started to burning, it would be very difficult to extinguish the fire. The loss of the accident was that 10 containers of 20-foot and 35 containers of 40-foot were totally destroyed, the cargoes of 49 containers were totally damaged and the economic loss was up to 10 millions RMB. (Chen & Lao, 2008).

2.2.2 The safety of the structure and body of containers

a. The main frame of the container should be intact, its side walls, roof and base structure should be in good condition, without any significant deformation.

b. The safety approval placarding and inspection approval marking should be shown clearly and the content should be effective according to the requirements of CSC convention. (Figure 2.2.2.b)

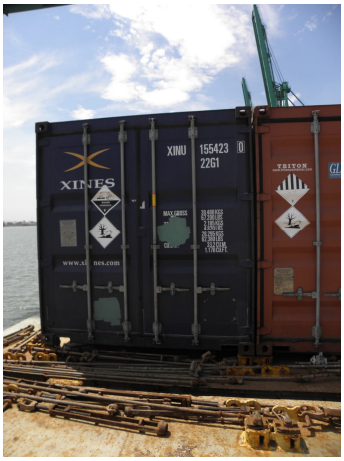

Figure2.2.2.b The safety approval placarding is not clear Resources: Database of T MSA

c. The inside of the container should be in clean and dry condition; there should be no water, oil, residual cargo in the container.

d. The corner fitting and loop fastener of containers should be in good condition.

e. There should be no pores, protrusions or other injures in the roof and side walls of the container.

f. The seal gasket of the container should be close enough to ensure that the container can be in the tightly close condition.

2.2.3 The packaging, marking and label of dangerous goods

a. The packaging of dangerous goods should be in good condition, there should be no damage, deformation or leakage in the package. (Figure 2.2.3.a)

Figure 2.2.3.a The packaging is broken Resources: Database of T MSA

b. Some attachments such as water, snow, ice, oil should be removed form the external packaging before loading.

c. The label and marking of dangerous goods should accord with the class of dangerous goods, and the size of marks should comply with the provision of IMDG code.

d. The location of markings should meet the following requirements:

——Boxes: The marking should be located at the side of the package.

——Bags: The marking should be located at the obvious place of the package.

——Drums: The marking should be located at the body or cover of the package.

——Intermediate Bulk Containers which capacity exceeding 450L: The marking should be located at the opposite sides. (Pisinger, 2002).

The marking of marine pollutants shall be located in the vicinity of dangerous goods marks; it should be located in the appropriate location if there is no dangerous goods mark.

e. The markings on the packaging of dangerous goods should be required to make the position toward the door, so that the class of dangerous goods can be identified easily while opening the door of containers. (Figure 2.2.3.e)

Figure 2.2.3.e The markings on the packaging are not toward the door Resources: Database of T MSA

f. The markings on the packaging of dangerous goods and containers should be posted securely, so that the markings are still visible after immersing in the seawater for at least 3 months.

g. The markings of the subsidiary label, marine pollutant, fumigation warning and UN number should not be lost. (Figure 2.2.3.g)

Figure 2.2.3.g The marking of packaging is missing Resources: Database of T MSA

2.2.4 The protection of packing crew and the working environment

a. The workers should wear appropriate protective materials while packing.

b. The sensitivity of weather should be paid attention to while packing. For example, the water in the containers caused by rain or snow should be cleaned in time; otherwise the packaging will be soaked. Meanwhile, the dangerous goods of flammable reaction class should be avoid to be loaded in high temperature. (Xue & Lai, 1997).

2.2.5 The secure, segregation and backing straps of dangerous goods in the container

a. To prevent the packaging from tilting upside down or air vent downwards for the drum, box and can, or the dangerous goods in the packaging would be spilled or dumped easily. (Figure 2.2.5.a)

Figure 2.2.5.a Some drums are downwards in the container Resources: Database of T MSA

b. The reasonable stacking is another important point for dangerous goods in the container. There are two methods to stack dangerous goods, the first one is "the solid should be placed on top of the liquid, and the light cargo should be placed on top of the heavy cargo", and the other one is to avoid random accumulation, or the packaging of dangerous goods would be broken and the goods would be spilled. (George, 1992). (Figure 2.2.5.b)

Figure 2.2.5.b The stacking of goods is too random Resources: Database of T MSA

c. When some different kinds of packaging in the container, the cushioning material is necessary between cargoes. In addition, effective gasket material is also needed between upper and lower drums while drums are loaded in the container. (Figure 2.2.5.c)

Figure 2.2.5.c The gasket material is not enough Resources: Database of T MSA

d. To pay more attention to the fastness of packaging in the container and avoid moving the package during the transportation. In addition, the pallet should be used carefully, especially when checking the condition of pallet strength. If the pallet is

not firm enough to support the dangerous goods, it is likely to cause the damage to the goods. (Figure 2.2.5.d)

Figure 2.2.5.d The pallet is broken Resources: Database of T MSA

e. We should fully consider the factors which can result in the movement of goods during the transportation, such as the vibration and sway of vessels. In particular, the secure between the dangerous goods and the door of containers should be paid more attention to. For example, the reinforcing wood is needed for each layer of drums when more than one layer of drums are loaded in the container. Meanwhile, we should use nylon rope to secure metal drums instead of steel wire rope, because the steel wire rope is much more vulnerable than nylon rope; what is more important, the steel rope is likely to make the friction with the metal drums, which would result in the accident during the transportation. (Figure2.2.5.e)

Figure2.2.5.e There is no reinforcing wood for the drums Resources: Database of T MSA

f. To avoid the condition of overweight in the container. In general, what can be seen as overweight for the total weight of 20 feet container is over 24 tons, or the total

weight of 40 feet container is more than 30.5 tons. Therefore, the loading weight of 20-foot container should be controlled at 20 tons or less, up to a maximum of 22 tons; the loading weight of 40 feet container shall not be more than 26 tons.

g. To avoid the uneven distribution of dangerous goods in the container, 60% of the cargo weight shall not be loaded in half the length of container. (Figure 2.2.5.g)

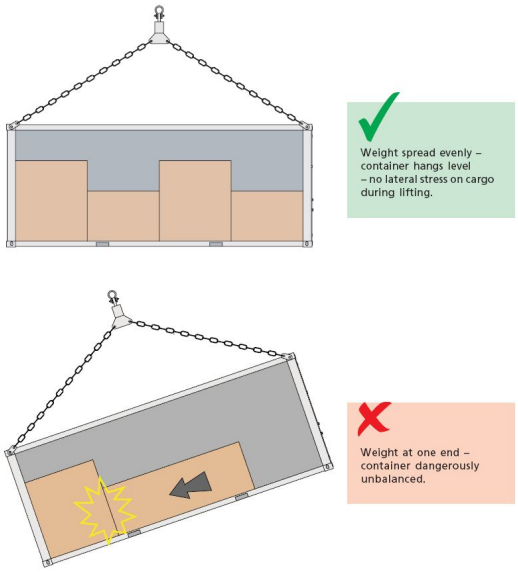

Figure 2.2.5.g The distribution in the container Resources: Database of T MSA

h. The dangerous goods should be placed in the position which is near to the door when the dangerous goods and general goods are loaded in the same container, which is beneficial to load the dangerous goods lastly and unload it firstly. (Figure 2.2.5.h)

Figure 2.2.5.h The dangerous goods are hidden inside general goods Resources: Database of T MSA

i. The less than container load (LCL) should be strictly in accordance with the regulations of segregation tables and limited quantity in IMDG code.

2.2.6 The special requirements for different class of dangerous goods

In addition, there are some special regulations for different classes of dangerous goods loaded in the container according to the provisions of IMDG code. For example, the wooden gasket should be used to separate the metal packaging from the side of the container for the dangerous goods of Class 1, and the parking tools must be forbidden while loading. For dangerous goods of Class 2, the cylinders helmet, bottle sidewall, valves, protection holster and other accessories of the steel bottles should meet the requirements and so on.

2.3 The stowage and segregation of containers carrying dangerous goods on board

The stowage and segregation of containers carrying dangerous goods on board has been an important issue in the world, as every aspect of the handling will directly affect the safety of the vessel, crew and cargo.

2.3.1 The hazard of non-compliance with the regulations of stowage and segregation

The Panamanian MV "HYUNDAI Fortune" caught fire and exploded at 60 nm from the southern coastline of the Gulf of Aden from Yemen on March 21, 2006. According to the inspection, the main reason for the accident was seven containers carrying dangerous goods of class 1 stowed in the rear of the ship. (Ji & Han, 2004). Because the ship`s engine was at the rear, the seven containers were actually stowed in the upper part of the engine room. According to provisions of IMDG code, the section 7.1.7.4.6 clearly states that goods of Class 1 shall be as far away from accommodation spaces and machinery spaces, and must not be stowed directly above or below these premises. Obviously, the stowage of these seven containers broke

regulations of IMDG code. (Figure 2.3.1)

Figure 2.3.1 The accident of "HYUNDAI Fortune" Resources: Investigation Report of "HYUNDAI Fortune"

2.3.2 Stowage

a. It should be in compliance with the general principles of stowage in the IMDG code. These general principles refer to all the stowage requirements in the Chapter 7.1 of IMDG code, including the general provisions, the stowage in relation to living place, the stowage of marine pollutants, particular stowage for dangerous goods of Class 1 to Class 9 and so on. (Wu & You, 2011). These requirements are less related to specific dangerous goods, so that the general principles are often easily overlooked in practice.

b. It should meet the special requirements of stowage for dangerous goods. As is known to us, even for dangerous goods belonging to the same class, the relevant requirements are quire different because there are a lot of differences in physical and chemical characteristic between different dangerous goods. (Pinter, 1995). As a result, the stowage of some dangerous goods is not safe enough if only the general principles are observed. Besides, the special requirements of stowage for each dangerous good is described in the section 16 "Stowage and segregation" of "dangerous goods list" in part 2 of IMDG code, such as the special stowage regulations for living space, marine pollutants, food-related stowage and so on.

c. It should comply with the specific requirements of the "Document of Compliance"

or "Certificate of Fitness for dangerous goods" in the vessel. According to the regulations of SOLAS 1974, when a vessel constructed after 1 September 1984 carrying solid dangerous goods, it must hold the "Document of Compliance" or "Certificate of Fitness for dangerous goods", which can prove that relevant equipments of vessel meet the requirements of the convention. The certificate is an important document for container ships carrying dangerous goods, and the annex of certificate shows which class of dangerous goods can be stowed in a particular cargo hold as well as relevant requirements. (Chen & Mao, 2008). It should be emphasized that the stowage in the vessel should comply with not only the regulations of "Document of Compliance" but also the regulations of IMDG code. In the experience of checking, the writer found that some crew made a mistake because they thought the stowage of ships only needed to comply with the "Document of Compliance" and did not have to comply with IMDG code any more.

2.3.3 Segregation

a. The segregation requirements of general condition.

According to the risk of dangerous goods, the segregation requirements can be determined by the segregation table in IMDG code. Most operation of segregation can follow the segregation table in practical transportation, but the precondition is that related dangerous goods are without accessory danger and there are no other special requirements of segregation.

b. The segregation requirements of dangerous goods with subsidiary risk

For the dangerous goods which have the subsidiary risk, if the segregation requirements for the subsidiary risk are much stricter than the requirements for the main risk, the segregation operation should comply with the requirements of accessory danger preferentially. In fact, the accident is likely to occur if the crew neglect the accessory danger of dangerous goods while segregating. (Gu & Yi, 2006).

c. The segregation requirements for special segregation

If some special segregation regulations listed in the "Stowage and Segregation" of IMDG code apply to certain dangerous goods, then the dangerous goods should comply with the special regulations firstly. It should be noted that these special regulations are prior to the above two requirements (a and b of 2.3.3).

2.4 Undeclared containers carrying dangerous goods by sea

Undeclared containers carrying dangerous goods means that the shipper or carrier conceals the real information of dangerous goods to the maritime authorities and declare these cargo as the general goods. Generally, most of the cases of undeclared dangerous goods are not out of the intention by the ship; the main problem of undeclared dangerous goods is from the shipper, as the great difference in the freight between the dangerous good and the general goods usually results in the occurrence of undeclared dangerous goods. Meanwhile, containers also provide a very convenient condition to hide undeclared dangerous goods.

2.4.1 Introduction to undeclared dangerous goods

The undeclared containers carrying dangerous goods by sea will cause the great risk to the maritime transportation; it also is the huge threat for the ships, crew, cargoes and environment protection. The MV "Hua Ding Shan" caught fire during the voyage from Shanghai port to Guangzhou port in May 2003 and the ship sank soon. The main reason was that the container TGHU2511096 in the vessel declared as ferric oxide, but the actual cargo in the container was sodium dithionite (hydrosulfite, class 4.2). (Zhang, 2008). Besides the safety risk, the undeclared dangerous goods also will disrupt the normal marine market and make the unfair competition, even affect the running of whole trade supply chain for the world shipping.

In recent years, all port states in the world have strengthened the inspection for

undeclared containers carrying dangerous goods. Taking the port T of China as an example, the number of verified undeclared containers carrying dangerous goods was up to 30. During the inspection, it was a very useful method to check the manifests of vessels. The container MSKU4384888 loaded in MV "MAERSK DELANO" at the voyage 1210 was suspected to carry the undeclared dangerous goods in May, 2012. After the further inspection, inspectors found that the calcium chloride (class 5.1, UN No. 2880) in the container was declared as the general good by the shipper. (Figure 2.4.1.a)

Figure 2.4.1.a The container MSKU4384888 Resources: Database of T MSA

Inspectors of Port T found that there were 24.096 ton "SULFAMIC ACID" (class 8, UN No. 2967) in the container TEMU2508151 which was loaded in the MV "CMA CGM PEGASUS" at the voyage FM540W in March, 2013,, and the cargo was not declared to the maritime administration. According to the inspection, the reason was that the shipper did not explain the real information of the cargo to the carrier before loading. (Figure 2.4.1.b)

Figure 2.4.1.b The container TEMU2508151 Resources: Database of T MSA

2.4.2 The main reasons for undeclared dangerous goods

a. The first reason is that the freight of dangerous goods is much higher than general goods. Generally, the freight for a container carrying dangerous goods is 50%—100% higher than a container carrying general goods, or even higher. While the freight for a refrigerated container carrying dangerous goods is 150% -200% higher than a refrigerated container carrying general goods. As a result, some shippers, consigners or agents have their choices to declare the dangerous goods as the general goods so that the freight can be saved a lot. (Huang & Qian, 2010).

b. Another reason is some transportation restrictions for some dangerous goods. At present, some countries often prohibit certain dangerous goods to be transported in their countries for various reasons, and some dangerous goods are forbidden to transport in some shipping companies. (Zhai, 2007). For example, the lighters are forbidden to be imported in some European countries now; explosives of Class 1 could not be imported in United States after 911 terrorist attacks; sulfur dioxide and calcium hypochlorite could not be carried by the OOCL and some other companies, and so on. In this case, the shipper had no choice but to change the name of dangerous cargoes which were forbidden or provide false information to transport these dangerous goods in some countries or some companies.

c. A lack of professional knowledge for dangerous goods is also an important reason for undeclared containers carrying dangerous goods. (Zhao, 2007). On the one hand, some shippers do not understand the relevant information of transportation for dangerous goods, even they do not realize whether the cargo is dangerous goods or not, or do not know the regulations for dangerous goods in maritime transportation, which will easily lead to the occurrence of undeclared dangerous goods. On the other hand, with the rapid development of the chemical industry globally, the amount and kinds of chemical products have increased rapidly; some new dangerous goods still can not be listed in the IMDG code now.

2.4.3 The main measures to deal with undeclared dangerous goods now

a.The measures for carriers

The carrier should correctly identify the relevant transportation documents provided by the shipper, and the employers who are responsible for the operation should be familiar with the correct name and information of dangerous goods. (Chen, 2007). To set up the cargo database is a useful method to prevent undeclared dangerous goods by shipper. When the bill of lading is entered, the system will make the appropriate prompt or warning, which is beneficial to keep the consistency between the cargo and its transport documents and prevent the occurrence of undeclared dangerous goods effectively.

b. The measures for maritime administration

As the authority for the maritime transportation of dangerous goods, maritime administration plays an important role in checking undeclared dangerous goods during the process of transportation. At first, maritime administration should strengthen the declaration checking of containers carrying dangerous goods with the methods of on- site inspection or verbal questions. (Wang & Liu, 2007).

Secondly, maritime administration should strengthen the management for agents and shipping companies. Generally, the declaration for the dangerous goods is in the charge of the native agent or the delegate of shipping companies, so how to manage the agent and delegate is very important for checking undeclared dangerous goods. Referring to the blacklist system of Port State Control, the maritime administration could open and exchange the information of companies whose undeclared containers carrying dangerous goods are investigated and punished according to the IMDG code and national legislations, and then the containers from companies of blacklist should be tracked particularly.

Thirdly, the port state should set up a series of legislations to punish the operation of undeclared containers carrying dangerous goods. The maritime administration should strengthen the punishment for undeclared dangerous goods. Besides, public tip-offs are encouraged for the safety management of containers carrying dangerous goods.

In addition, the administration may use new technology such as useful information system to strengthen the management of undeclared containers carrying dangerous goods. For example, Shanghai port in China developed the EDI system to declare the containers carrying dangerous goods. The maritime administration can inquire about the information of declaration and pre-booking on exports, track the suspicious container at any moment and open the suspicious container to inspect cargo inside in time. It has been proved that the accuracy of opening the suspicious containers is greatly improved by the EDI system. (Huang, 2008).

2.5 The emergency treatment for containers carrying dangerous goods by sea

2.5.1 The preparing of equipments for emergency treatment

The equipment for emergency treatment of containers carrying dangerous goods mainly includes the fire-fighting equipment and personnel protective equipment.

a. The attention should be paid to the main fire pumps and emergency fire pumps of the vessel, the fixed fire-fighting facilities and mobile fire-fighting facilities in the port and container freight stations. For example, the inspector should inspect if the facility can spray the water in time if the water pressure can meet the requirements. The hose, fire-fighting lance should be in good condition, the extinguishers should be effective and the number should be enough. The regular inspection is necessary for the emergency facilities, and the safety risk must be immediately corrected to ensure that all the facilities are in good condition at any moment. (Jiang, 2006).

b. According to the requirements of Chapter Ⅱ-2 of SOLAS 1974, the fire-protection clothing, full chemical protective clothing and self-contained breathing apparatus should be equipped adequately and placed at available position in the ship, port and container freight station. (Liu & Yin, 2006). The crew in the ship, port and container freight station should be trained to learn how to use these facilities periodically and regular drills are also needed.

2.5.2 The relevant training for crew including sailors and workers ashore

a. To strengthen the training of basic knowledge of dangerous goods for crew including sailors and workers ashore. The crew should be familiar with the characteristics of dangerous goods, which is beneficial to stow and segregate the dangerous goods reasonably according to the regulations of IMDG code.

b. The attention should be paid to the emergency response capability of crews including sailors and workers ashore in the accident. The emergency response capability relates to the ability to control the accident of containers carrying dangerous goods, and the appropriate response measures can avoid or reduce the loss and damage of the incident. The ships, ports and container freight stations should conduct regular emergency drills and ask the crew to fulfill their responsibility according to the requirements of muster list and take appropriate measures in time. (Zhao, 2007).

2.5.3 The emergency measures for the leaking of containers carrying dangerous goods on board

The class of dangerous goods	The emergency equipment	The emergency measures（leaking on the deck）	The emergency measures（leaking under the deck）

Class 1	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3. The soft brush, plastic drums 4. Absorbing material	1. To clean up the leaked goods timely 2. To Keep the humidity of scene 3. To Wash the spilled good with plenty of water	1. To Keep the humidity of scene 2. The damaged packaging shall be collected for safe handling as soon as possible if it is allowed.
Class 2	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which complies with the SOLAS 1974	1. To evaporate the liquefied gas leaked if the condition allowed, but crews must stay away. 2. The damaged packaging shall be collected for safe handling if it is allowed	1. To make adequate ventilation as far as possible. 2. To evaporate the liquefied gas leaked if the condition allowed, but crews must stay away.
Class 3	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which complies with the SOLAS 1974 4. Absorbing material	1. To clean up the leaked goods timely in the safe way 2. The spilled cargo should be collected with the absorbing material for safe handling if it is allowed	1. To make adequate ventilation as far as possible. 2. The spilled cargo should be collected with the absorbing material for safe handling if it is allowed

Class 4	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which complies with the SOLAS 1974 4.Inert absorbing material	1. The spilled cargo should be collected with the absorbing material for safe handling if it is allowed 2. To Wash the spilled good with plenty of water 3. To control the melting goods with the inert absorbing material	1. The spilled cargo should be collected with the absorbing material for safe handling if it is allowed, and the operating record should be noted in time.
Class 5	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which complies with the SOLAS 1974	1. To wash the spilled good with plenty of water 2. To prevent further spilling as soon as possible	1. To make adequate ventilation as far as possible. 2. To take appropriate safety measures according to the degree of leaking
Class 6	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3. Absorbing material	1. To wash the spilled good with plenty of water if it is allowed 2. The spilled cargo should be collected with the absorbing	1. To make adequate ventilation as far as possible. 2. The spilled cargo should be collected with the absorbing

		material for safe handling if it is allowed	material for safe handling if it is allowed, and the operating record should be noted in time.
Class 7	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which complies with the SOLAS 4.Inert absorbing material	1. To seek the advice of experts as quickly as possible. 2. The spilled cargo should be covered with the inert absorbing material 3. The polluted equipment should be collected and separated by the effective material 4. To wash the spilled good with plenty of water, but crews must stay away.	1. To seek the advice of experts as quickly as possible. 2. The spilled cargo should be collected with the inert absorbing material for safe handling if it is allowed
Class 8	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which	1. The spilled cargo shall be covered with the wet sand. 2. To wash the spilled good with plenty of water, but	1. The spilled cargo should be collected with the absorbing material for safe handling if it is allowed, and the

	complies with the SOLAS 4. Absorbing material	crews must stay away.	operating record should be noted in time. 2. To prevent further spilling as soon as possible
Class 9	1.Protective clothing, boots, gloves, helmets 2.Self-contained breathing apparatus 3.The spray fire-fighting gun which complies with the SOLAS 4. Absorbing material	1. To prevent further spilling as soon as possible 2. To wash the spilled good with plenty of water, but crews must stay away.	1. To seek the advice of experts as quickly as possible. 2. To make adequate ventilation as far as possible. 3. The spilled cargo should be collected with the absorbing material for safe handling if it is allowed.

Table 2.5.3 The emergency measures for leaking of containers carrying dangerous goods

Chapter 3. The safety and risk management of containers carrying dangerous goods by sea based on FSA

3.1 Introduction to FSA

The maritime shipping is a collection of industries; its safety assessment can mostly use the experience of other industry fields. The formal safety assessment (FSA) is an assessment system which uses the experience of risk management and combines the characteristic of maritime industry. (Fang & Wang, 2004).

The risk management is to control the risk effectively and deal with the risk with the most economical method by the process of identifying risks, measuring risk and analyzing risk, so that it can achieve the scientific management method of optimal safety production. (Qin & Cheng, 2008). The diagram of risk management and the flowchart of FSA are shown as below. (Figure 3.1.a Figure 3.1.b)

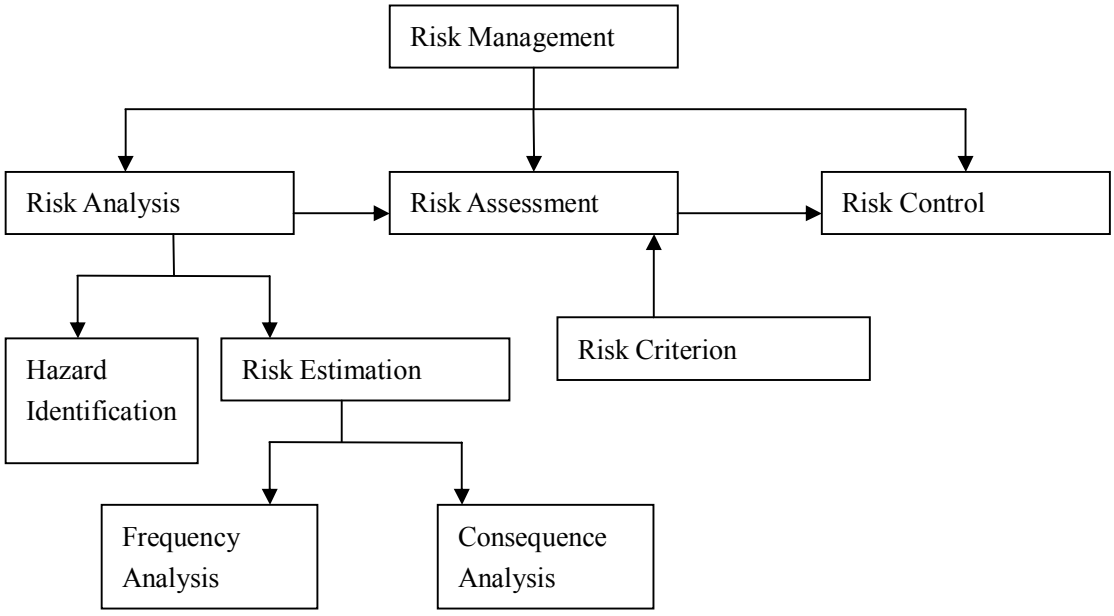

Figure 3.1.a The diagram of risk management

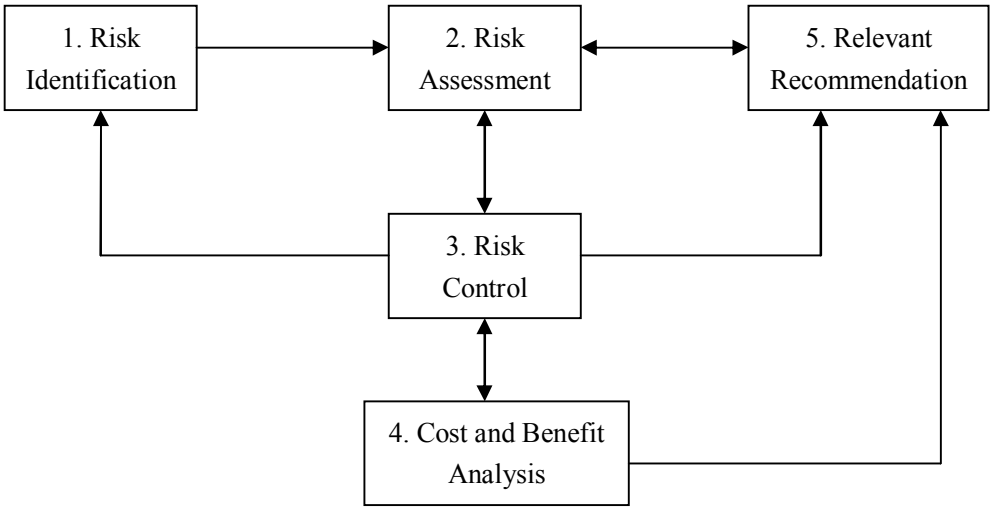

Figure 3.1.b the flowchart of FSA Recourse: Guidelines for Formal Safety Assessment (FSA) For Use in the IMO Rule-Making Process

FSA is a comprehensive, structured and systematic assessment method, which can establish reasonable rules and provide a risk control program.

The FSA has are two purposes:

The first purpose is to reduce the frequency of accidents. From the comprehensive and long-term perspective, it is unrealistic to avoid accidents or make the probability of incidents zero or close to zero, but it is available from the partial perspective.

The second is to reduce the consequences of accidents. From the point of the severity of the consequences, it can reduce the consequences of its occurrence. From the point of the economy, it can reduce the cost to an acceptable range. As a result, the cost and benefit analysis is necessary to provide the scientific basis to develop or modify the appropriate measures, and it also can play an important role in the suggestion and advice for maritime safety. (Xu, 2006).

There are five standardized assessment procedures in the FSA, including the risk identification, risk assessment, risk control options, cost and benefit analysis and

relevant recommendations for decision-making. Based on the condition of actual works, it summaries and analyzes the safety situation firstly, then revises some original regulations or establishes new safety standards and operational criteria to improve relevant technical procedures, and make the measures achieve coherence between costs and benefits. For the purpose of the management of containers carrying dangerous goods, the result of FSA can be formulated as a modified safety standards, and it can also provide information to improve the management level of containers carrying dangerous goods. (Qin & Cheng, 2005).

3.2 The risk identification for containers carrying dangerous goods by sea

According to the definition of the International Maritime Organization, the hazard means "the potential threat of the safety of life, health, property and the environment". (IMO, 2002). Hazard can be described as all the possible factors causing an incident or event of containers carrying dangerous goods by sea in the risk management of containers carrying dangerous goods by sea.

The risk identification is the first stage of FSA for containers carrying dangerous goods by sea, its goal is to identify all potential risk causing the accident of container carrying dangerous goods and sort it out according to its risk level. This stage aims to analyze a series of questions such as which, when and where the risk will occur and why the risk occurs. (Wang, 2011). A series of methods and technology are necessary to systematically analyze the information of containers carrying dangerous goods by sea so that the risk can be identified comprehensively.

The information which should be received in this step includes:

(1) The comprehensive risk list and its related scenarios which can result in the accident are the first necessary information. Besides, the risk or its scenarios should be sorted according to its risk level.

(2) The potential reason and consequence of each risk is also needed in this stage. By calculating the risk index, the risk and its related scenarios can be sorted out according to the risk level. The high level risk will be analyzed further, and unimportant risk will be ignored.

3.3 The risk assessment for containers carrying dangerous goods by sea

This step includes two main elements: the risk analysis and risk assessment. At the stage of risk identification, the important risk and its related scenarios should be identified. However, at the stage of risk analysis, the reason and consequence of relevant risk and its scene should be analyzed, including the effect on the whole event caused by each factor. The consequence of the risk and the probability of accident will be estimated, too. Many factors should be consulted to determine the acceptable risk standard, such as the level of economic development, legal norms, the value of natural resources, the sensitivity of the coastal waters, and the capability of the rescue and clean-up. If the risk level of containers carrying dangerous goods by sea is higher than the acceptable risk standard, appropriate measures should be taken to control the risk. (Ni & Zhang, 2009).

a. The risk analysis

An important evaluated method of risk assessment is risk analysis. Nowadays, the definition of risk is not very uniform because of the different targets. In general, there are two considerations for the risk. Firstly, the risk can be seen as the probability of adverse event or improper event in the system. Secondly, the risk can be described as the product between the consequences of the incident and the probability of the incident happening. Thus, the formula can be calculated: the degree of risk = the Probability of risk $\times$ the consequence. In many cases, it is more appropriate to use the degree of risk because it can not only include the probability of risk but also reflect the harmful consequences.

In general, the process of the risk analysis is to assess the likelihood and possible consequence of the most important risk scenarios systematically. The risk analysis is shown as the following diagram. (Figure 3.3.a)

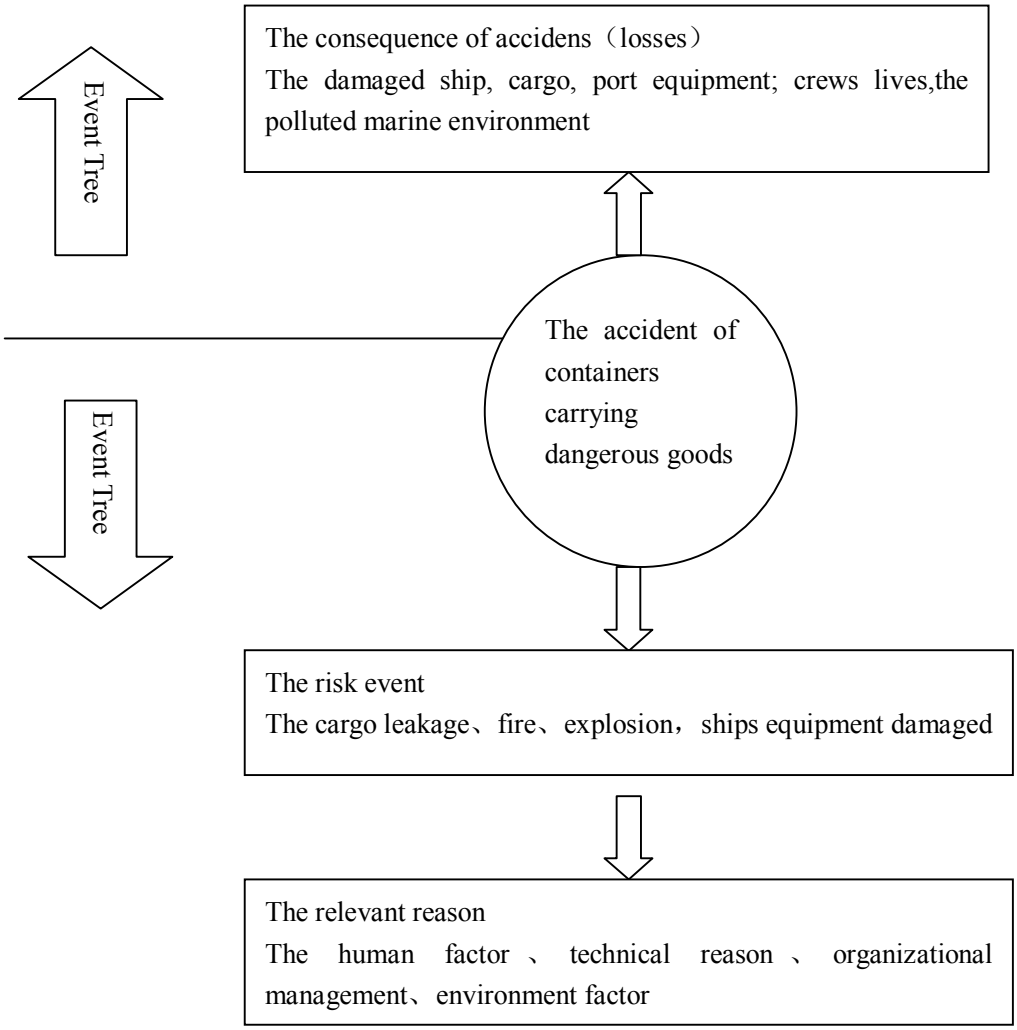

Figure 3.3.a The risk analysis

b. The risk assessment

Generally, there are many victims in an accident of containers carrying dangerous goods by sea, so we should analyze it from the point of the social risk. Based on the frequency and severity of risk level, the FN curve in the FSA can be used to assess the risk of containers carrying dangerous goods by sea. The b in the FN curve is the frequency of accidents at sea, while N originally refers to the number of casualties.

The FN curve can be made by determining the number of acceptable casualties under the frequency of accidents, and the curve can be accepted as the risk standard. (Fang & Yang, 2005). Similarly, N can stand for the quantity of cargo loss in the incident of containers carrying dangerous goods. As a result, the acceptable risk standard of containers carrying dangerous goods can be determined by the FN curve. The factors needed to be considered when the risk standard is determined in the accident including the direct economic losses, the time required to clean up the spill, the effect for environment system, the capability of emergency response operations. In addition, the historical data and legal requirements should be fully considered in the process of determining the risk criteria and the communication and exchange with all relevant stakeholders is also necessary.

3.4 The risk control option for containers carrying dangerous goods by sea

The risk control methods (RCM) refer to the controlled measures of single factor in the FSA, while the risk control option (RCO) refers to a combination of a series of risk control measures. After identifying the risk of containers carrying dangerous goods and analyzing the risk, it is necessary to find the appropriate risk control measures and integrate them into risk control options. This process may include four steps:

a. To determine the main risks which need to be controlled;
b. To list all the possible risk control measures;
c. To evaluate the cost-effectiveness of each risk control measures;
d. To integrate reliable risk control measures into the risk control option. (Wang, 1994).

In order to make the risk control option efficient and available, some certain principles should be followed. The risk control option should not only include the

preventive measures which can prevent the occurrence of accidents but also include the controllability measures which can reduce the loss after occurrence of accidents.

3.5 The cost and benefit analysis for containers carrying dangerous goods by sea

After making the risk control option, the next step is to make the cost and benefit analysis of all possible risk control options. The cost and benefit can be measured by a series of indicators, such as the spilled dangerous goods which were received in the coastal water. The preventive control measures aim at avoiding the occurrence of accidents of container carrying dangerous goods by sea, and the measure can be assessed by the per unit cost of the number of accidents avoided.

The important point of this step is to assess all kinds of risk control measures from the perspective of economy, assess the cost needed for taking the measures and the benefit of risk reduction after taking the measures. The cost and benefit analysis is beneficial to decide which technique and operation should be taken. For example, how many emergency equipments should be prepared according to the quantity of storage and handling for containers carrying dangerous goods in the port or container freight station? How to train a professional emergency team to deal with accident timely? Besides, the cost and benefit analysis should also allow people to understand the economic loss if the measure is not taken in time, which is helpful to allow executives to understand the necessity of taking the measure and emergency preparedness in advance. (Wang & Foinikis, 2011).

3.6 Relevant recommendations for decision-making

The recommendation for decision-making is the last step of FSA. The primary process and the final finding should be described detailedly in making recommendations. Firstly, the comprehensive background of containers carrying

dangerous goods by sea should be introduced, such as the information of coastal waters, the experts who will participate in the assessment. In addition, the key assumptions, limitations, and data models and research methods in the assessment should also be introduced simultaneously. As the risk analysis (also including risk identification) and cost-benefit assessment is the core of the FSA, these two processes in the recommendation should be systematically elaborated on. Through the risk analysis, some questions can be answered, such as why the risk of containers carrying dangerous goods should be controlled and which risk should be controlled. Meanwhile, the optimal risk control scheme can also be determined by the cost benefit analysis. At last, all the findings of FSA should be written in the recommendations of decisions in a logical and systematic way.

Chapter 4. Conclusion

With the rapid development of the world economic and maritime industry, the accident of containers carrying dangerous goods by sea has become an important source of the safety risk in the world shipping. A series of serious accidents of containers carrying dangerous goods shocked the whole world, which also caused huge losses for vessels, crew, cargoes and ecological environment. How to strengthen the safety management of containers carrying dangerous goods by sea has become a hot issue for the world shipping recently.

Nowadays, the risk source for the container carrying dangerous goods by sea mainly includes five aspects: the packing of containers, the stowage and segregation in the ship, undeclared dangerous goods and the emergent measures. Through the introduction to the FSA and its application in the containers carrying dangerous goods by sea, we can learn that the FSA is effective tool to strengthen the management of containers carrying dangerous goods and prevent the occurrence of accidents, and it also has important significance in reducing the loss of accidents and taking the appropriate measures in the accident timely.

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