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Risk assessment on carriage of maritime dangerous goods in packaged form by ship

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RISK ASSESSMENT ON CARRIAGE OF MARITIME DANGEROUS GOODS IN PACKAGED FORM BY SHIP

By

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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

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ABSTRACT

Title of Research paper: **Risk Assessment on Carriage of Maritime Dangerous Goods in Packaged Form by Ship**

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Dangerous goods are such substances with the characteristics of explosion, inflammability, toxicity, corrosion, radioactivity, etc. Compared to general cargo transport, dangerous goods transport is more hazardous. Once accident occurs, it will endanger the safety of life, property and marine environment seriously. In order to improve safety of maritime dangerous goods transport fundamentally, it is necessary to analyze the risk in logistics chain of maritime dangerous goods and find out the risk factors at each link through quantitative analysis, which not only can prevent dangerous goods accident from occurring again, but can provide reference basis for maritime authority and relevant shipping enterprises when they establish precaution measures for maritime dangerous goods transport. So, it has realistic significance. In the paper, there are five chapters, including:

In Chapter1, background, objectives, methodology and structure of the research are introduced.

In chapter2, through comparison of law and regulation of maritime dangerous goods and its current implementation situation in China and at broad, it finds out existing problems in regulatory system of maritime dangerous goods at home.

In chapter3, it focuses on the requirements of packaging, labeling, classification, stowage and segregation of maritime dangerous goods, and analyzes the possible risk factors in the process of land transport and marine transport.

In chapter4, based on the risk evaluation and quantitative analysis of maritime dangerous goods, it establishes the maritime dangerous goods fault tree. In addition, through establishing the risk attribute table of dangerous goods container, it provides objective basis for maritime authority to select suspected container for inspection.

In chapter5, the conclusion is addressed on the basis of risk identification and assessment.

Key words: Maritime dangerous goods, Transport, Risk analysis, Risk assessment

LIST OF ABBREVIATIONS

MOT	Ministry of Transport of China
USA	the United States of America
EU	European Union
CFR	Code of Federal Regulations
HMR	Hazardous Materials Regulations
ECB	European Chemicals Bureau
REACH	Regulation concerning the Registration, Evaluation, Authorization and Restriction of Chemicals
ECHA	European Chemicals Agency
CLP	Classification Label and Package
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
DSD	Dangerous Substances Directive
DPD	Dangerous Preparations Directive
MSDS	Material Safety Data Sheet
LCL	Less Than Container Load
FCL	Full Container Load
IMDG Code	International Maritime Dangerous Goods Code
EmS	The EmS Guide: Emergency Response procedures for Ships Carrying Dangerous Goods
CSC	International Convention for Safe Containers, 1972, as Amended
CCS	China Classification Society
ISO	the International Organization for Standardization
MSA	Maritime Safety Authority

IMO	International Maritime Organization
FTA	Fault Tree Analysis
HRC	High Risk Container
LRC	Low Risk Container

CHARPTER 1: Introduction

1.1 Background

With the development of international trade and shipping industry, container transport has made considerable development. In 2014, Chinese ports have completed container throughput 202 million TEU, increasing by 6.4% over the previous year. Among them, coastal port finished 182 million TEU and inland ports completed 20 million TEU, increasing by 7.1% and 0.6% respectively over the previous year. (MOT, 2015) Fast development of container transport depends on the advantages of container transport. Carriage of cargo by container has a lot of advantages, including reducing damage or loss of cargo, improving the transportation quality, saving a lot of packaging costs, reducing logistics costs and increasing efficiency of loading and unloading at port, shorting the time of staying at port and accelerating the turnover of goods, and so on.

In making full use of container transport convenience, at the same time, there are many new security risks. Safety and pollution accidents of maritime dangerous goods in the process of loading and unloading operation or transport at sea may cause huge harm and loss to safety of life, property and public interest. For example, in August, 2012, container ship “MAERSK KUANTAN” registered in Singapore encountered leakage accident of dangerous goods in YANTIAN port. Two dangerous goods containers combusted and discharged large amounts of toxic gases into the air, causing great panic to the surrounding residents. In August, 2009, Chinese container ship “HANG LONG 518” dropped 12 dangerous cargo containers in to Yangtze River, causing great hidden hazard to drinking water of downstream cities. In August, 2006, during loading and unloading operation of China shipping “Melbourne” in Ningbo Beilun terminal 3#, one container carrying dichloro benzoyl peroxide that the shipper has made a concealed declaration to carrier started decomposition explosion, which was caused by dangerous chemical spill. (Zhang, 2010, P. 08) The occurrence of dangerous cargo accident closely related to concealed declaration, false declaration,

poor packing quality of dangerous goods and other relevant factors. Relevant data show that with the increase of transport and category of dangerous goods, accident of dangerous goods showed an increasing trend year by year, so it is urgent to strengthen the safety supervision of dangerous goods transport.

Dangerous goods in the process of production, operation and transportation will involve cargo handling, container loading and unloading, land transport, storage, maritime transport and many other links, even for a slight mistake in any connection, it may lead to serious catastrophic consequences. Based on the above reasons, how to strengthen safe management of dangerous goods and to reduce the accident of dangerous goods is the major problem of maritime authority, container yard, cargo freight station and relevant transport enterprises engaging in dangerous goods transport business. Although China has developed strict legal norms for maritime dangerous goods transport, Chinese MSA still lacks efficient management measures for maritime dangerous goods due to limitation of power and responsibility.

1.2 Objective of research

Research on safety issues of maritime dangerous cargo has following purposes:

1) Safety

Safety issue of maritime dangerous goods transport runs through the whole links of production, packaging, land transport, loading and unloading at port and carriage on board. Any problem at any connection will cause immediate or potential impact on safe transport of dangerous goods. For China MSA, its function on safe transport of maritime dangerous goods is only limited to qualification management of personnel, license of marine transport, spot inspection and stowage of cargo on board. (2014 edition Guideline for Maritime Administrative law enforcement disclosure) However, the phenomenon of concealed declaration or false declaration of dangerous goods still often happens. So, the research on safe transport of maritime dangerous goods has

realistic significance.

2) Pollution prevention

The accident of maritime dangerous goods will also cause serious pollution to marine environment; especially for such dangerous goods with serious pollution hazard and toxic harm, once leakage happens, it will cause a great threat to human and marine environment. So, the research on safe transport of maritime dangerous goods has important significance for pollution prevention.

3) Efficiency

According to SOLAS Convention Chapter VII and relevant Chinese regulations, ships carrying dangerous goods, the consignor or its agent should declare to maritime authority. Maritime authority should collect, analyze and sort relevant information of dangerous goods timely according to the declaration materials, and approve application of ship to enter, leave or transit port. Through establishment of dangerous goods registration system to replace inspection system and approval system of application, it will greatly enhance the administrative efficiency, simplify administrative procedures, and promote the speed of cargo circulation.

4) Responsibility

According to Chinese laws, enterprise is the main body of safety production. (Work Safety Law of the People's Republic of China (2014))However, some enterprises do not fully realize its safety responsibility as main subject of safety, which always depend on administrative supervision at large extent, even escape safety responsibility deliberately. So, the research on the whole logistics chain of dangerous goods is conducive to clear safety responsibility of enterprises and maritime authority.

1.3 Main contents of research

1）To identify and evaluate the risk in the process of dangerous goods transport through analysis of the whole logistic chain.

2）To analyze the safety management mode and related administration mechanism of maritime dangerous goods in EU and the USA, through comparison and analysis of domestic practice, and to find out the weakness of safety management of maritime dangerous goods in China.

3）Through risk identification and assessment, to establish domestic safety management system and mechanism for maritime dangerous goods.

1.4 Structure of research

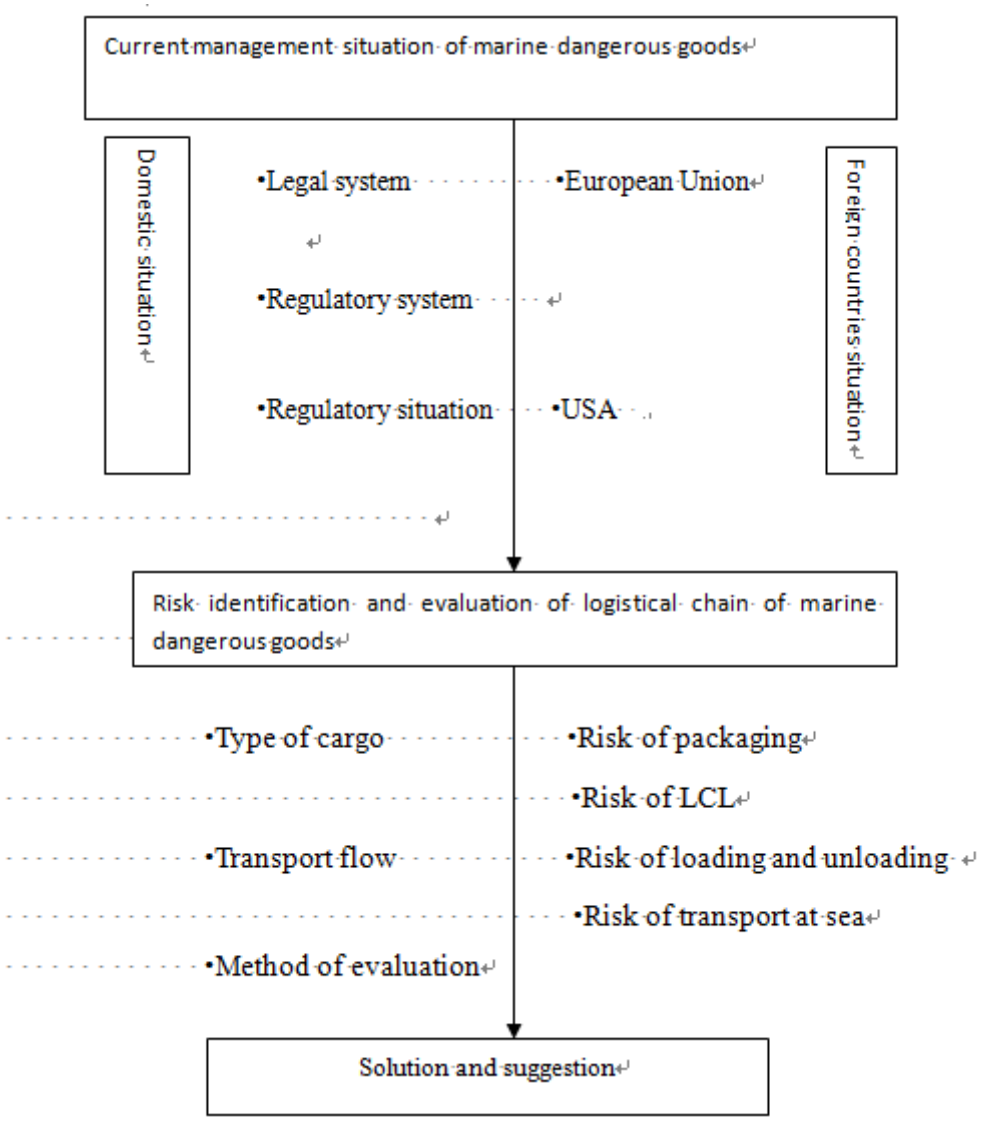

Diagram 1-1: structure of research

Source: author

Chapter 2: Current management situation of maritime dangerous goods in China and at abroad

In the chapter, I will analyze the current existing regulatory status of maritime dangerous goods on the basis of the logistics chain, laws and regulations.

2.1 Safety management status of maritime dangerous goods at abroad

2.1.1 Current management situation in the USA

2.1.1.1 Legislation of maritime dangerous goods transport

The United States has enacted laws for dangerous goods transport as early as 100 years ago. From "Act to Promote the Safe Transportation in Interstate Commerce of Explosives and other Dangerous Articles" promulgated on May 30, 1908 to "Title 49 -Transportation, Code of Federal Regulations"(CFR49) approved in the 90's of last century, the supervision of dangerous goods transport in various modes, from legislation to law enforcement, become more perfect gradually. (Zhang, 2009, P.48）

Part 100 to185 of CFR 49, namely "the Hazardous Materials Regulations (HMR)", covers relevant regulations of waterway, railway, road, aviation and other transport modes covering domestic and international transport of dangerous goods, including specific provisions of classification, packaging, labelling, loading and unloading operation and dangerous goods transport, etc. (CFR 49, 2012)The HMR also includes the provisions of security plan, emergency response, training rules of dangerous goods, bulk container and cylinder, etc. All of the regulations are not only in line with the current international Code, such as, "Orange Book" and "IMDG CODE", but also are close to domestic actual situation. (Zhang, 2009, P.48)Compared with international Code, those regulations have made necessary amendments. Some provisions are even more stringent than the international Code.

In general, American laws and regulations of dangerous goods transport are rigorous and high level. The contents are clear and concrete, and the procedures is clear with strong operability. Especially the key field of legislative purpose, principle, purpose,

methods, and key issues such as law enforcement subject, fully embodies the interest, sovereignty and intention of the state.

2.1.1.2 Major measures of safety management for maritime dangerous goods

The main approaches for US Coastal Guard to supervise safe transport of maritime dangerous goods, including:

1) **Registration system**. The state implements registration system for companies and ships engaging in dangerous goods transport. According to regulations, ships entering into port are required to fill declaration form and submit it to Coastal Guard for file on record for reference, but don't need to be approved by Coastal Guard. If any problem or accident happens, the record and verification of real situation will be taken as the basis of proofs. In addition, for the ships that must be approved by coast guard before entering into port, once being approved, if any problem or accident happens, the coast guard should be responsible for it. (Zhang, 2003, P.21)
2) **Inspection regime.** Coastal Guard has right to inspect the ships carrying dangerous goods, port and dock facilities in accordance with maritime laws. For example, for dangerous goods containers, when Coastal Guard carries out inspection, it mainly focuses on accuracy of declaration, structure of container body and stowage, segregation, dunnage, lashing and labelling of dangerous goods, etc, and random inspection is the main way. In addition, sometimes, joint inspection will be carried out with port authority, environmental protection department or fire fighting department. (Zhang, 2003, P.21)
3) **Punishment.** For any illegal behavior being found in the regulatory enforcement, the Coast Guard will resort to appropriate punishment measures according to law, and sometimes the punishment is quite serious until the enterprise going to bankruptcy. (Zhang, 2003, P.21) The people who have violated criminal law will be transferred to court.

2.1.2 Current management situation in the EU

2.1.2.1 Safety management institution of dangerous goods in the EU

The EU established European Chemicals Bureau (ECB) in January 1993. Main duties of the Bureau is to implement and coordinate chemicals management regulations and directives of the EU, to provide scientific and technical support work, and to undertake the work of chemical data connection and evaluation. (Wang & Tao, 2013, P.120)

Regulation concerning the Registration, Evaluation，Authorization and Restriction of Chemicals (REACH) was issued on 1 January, 2007. REACH is preventive management regulations for all chemicals into the EU market. The competent authority is the European Chemicals Agency (ECHA) that replaces some functions of ECB. REACH directive requires that the chemicals being imported and produced within the territory of the EU must be through a set of integrated programs of registration, evaluation, authorization, and restriction, etc, so as to identify the chemical composition to achieve the objective of ensuring the safety of environment and human better and more easily. (ECHA)

In addition, chemical safety authorities in EU member countries are responsible for accepting the declaration of new chemical substances and safety supervision of chemicals.

2.1.2.2 Safety management regulations of maritime dangerous goods in the EU

The safety management regulations of maritime dangerous goods in the EU include REACH and Classification, Labelling and Packaging (CLP).

REACH mainly includes several items of registration, evaluation, authorization and restriction. Registration refers that the annual production or import of such chemicals over 1 tons need to be registered, and for annual production or import of chemical substances more than 10 tons, chemical safety report should also be submitted to competent authority. Assessment includes archives evaluation and substance

evaluation. Archives evaluation is to verify the integrity and consistency of registration information submitted by enterprises. Substance evaluation refers to confirming the risk of chemicals to human health and environment. Authorization means that the import and production of chemicals with certain risk characteristics should be authorized. Restriction means that if the risk of chemicals to human health and environment cannot be adequately controlled, it will be limited to be imported or produced within territory of the EU. (Regulation concerning the Registration, Evaluation，Authorization and Restriction of Chemicals (2007))

CLP is a regulation related to classification, labelling and packaging of chemicals, and covers all possible harmful substances. The CLP Regulation can be traced to "Globally Harmonized System of Classification and Labelling of Chemicals (GHS)", and coexist and supplement each other with REACH Regulation. The Regulation replaced two previous pieces of legislation, Dangerous Substances Directive (DSD) and Dangerous Preparations Directive (DPD). The role of the regulation is to ensure that the hazard of all chemicals can be communicated to workers and consumers to make sure safety during handling operation through labelling and classification of chemicals. (Classification, Labelling and Packaging (2009))

2.2 Management status of maritime dangerous goods in China

China MSA is the maritime administrative law enforcement agencies on behalf of the state to fulfill the maritime safety supervision and management responsibilities. For maritime dangerous goods in package form, its regulatory role is mainly reflected in the following:

1) Declaration and approval management of dangerous goods
2) Spot supervision of dangerous goods, includes container packing inspection on site and pre-shipment inspection.
3) The emergency response for accident of dangerous goods.
4) Supervision and inspection against concealed and false declaration of dangerous goods.

5) Management of LCL dangerous goods
6) Management of dangerous goods declarer and container packing inspector

2.2.1 Declaration and approval management of maritime dangerous goods

1) Law and regulation

Article 33 of Maritime Traffic Safety Law of the People's Republic of China stipulates that when vessels load and transport dangerous goods, they must declare to local competent authorities, and may not be permitted to enter or leave harbor or load or unload until approval has been obtained from authority. (Maritime Traffic Safety Law (1984))

Article 67 of Marine Environment Protection Law of the People's Republic of China and article 22 of Regulations on Administration of Prevention and Control of Pollution to the Marine Environment by Vessels all stipulate that ship carrying harmful polluting goods in or out of port, his carrier, cargo owners or agents, shall apply to competent authority before entering or leaving port, transit stop or engaging in loading and unloading operation. (Marine Environment Protection Law (2000))

2) Current situation of implementation

Dangerous goods declaration is an important link of safety supervision and management for ships carrying dangerous goods. The implementation process is:

1. Ships carrying dangerous goods, shipper or its agent declare to maritime authority according to regulation.
2. Maritime authority should analyze, sort and verify the dangerous goods information according to declaration material.
3. To approve the application of ships to enter, leave port or transit.
4. To supervise the handling operation of dangerous goods at port.

The key points of approval for maritime dangerous goods declaration include: Strictly review dangerous goods declaration, verify classification of dangerous goods, and analyze the condition, safety and pollution prevention measures and emergency response measures of dangerous goods.

1. Verify whether there are incompatible dangerous goods loaded in a container
2. Verify the stowage position of dangerous goods to ensure correct stowage on board according to nature and classification of dangerous goods.
3. Ensure that each side of container has been marked properly in accordance with the requirement of IMDG Code.
4. For export dangerous goods, packing certification signed by qualified packing inspector should also be checked.

2.2.2 Spot supervision of maritime dangerous goods

Daily inspection and supervision is an important link to ensure safety of dangerous goods transport. Maritime authority should keep continuous track for imported and exported dangerous goods, check loading and unloading operation of dangerous goods frequently, inspect whether dangerous goods container have been posted dangerous marks as requirement, examine whether the container is in good condition, and verify dangerous goods list carefully, once any problem or illegal act is found, maritime authority should take corrective measures timely, even take punishment, detention and other measures, in order to improve the consciousness of ship-owners and cargo owners to execute regulations of dangerous goods.

1) Law and regulation

Article 25 of Regulations on Administration of Prevention and Control of Pollution to the Marine Environment by Vessels stipulates that if maritime authority doubts that harmful polluting cargo carried by ships should be declared but not be declared or the information of declaration is not correct, he has the right to open the container and

inspect cargo inside. (Regulations on Administration of Prevention and Control of Pollution to the Marine Environment by Vessels (2010))

2) Current situation of implementation

The inspection from maritime authority to imported, exported or transited dangerous goods mainly focuses on packing quality of dangerous goods. For general cargo, the inspection mainly concerns whether there is a behavior of concealed or false declaration.

For inspection of exported dangerous goods, it mainly includes following aspects: (Zhang. & Ge & Zhou, 2011, PP.148-149)

1. Whether the declaration of dangerous goods has been approved before shipment by maritime authority
2. Whether cargo in container has been properly packed in accordance with the requirements of IMDG Code.
3. Careful inspection should be carried out for the packaging of dangerous goods in container, and any damage, leakage and expansion deformation of packages should not be packed in container.
4. Careful and strict inspection should be carried out for container carrying dangerous goods. The container should be intact without damage, and its door can be closed smoothly and sealed completely. There is no residue or peculiar smell in container and no irrelevant markings outside of container.
5. Dangerous goods in container should be padded, lashed and fixed reasonably. The stacking of package should be neat, tight and no space is left.
6. Every container carrying dangerous goods should be posted proper markings consistent with the nature of dangerous goods

In the process of inspection, if concealed and false declaration of dangerous goods is found, penalty will be taken in accordance with relevant regulations. For deficiency of marking, labelling, stacking, lashing and stowage, etc, the container can be released only until the deficiencies have been rectified.

2.2.3 Management of LCL for dangerous goods

1) Law and regulation

According to the requirements of IMDG Code, dangerous goods that should be segregated with each other will not be permitted to pack in same container. And dangerous goods that should be away from each other can be loaded in same container with approval of competent authority. So, two or more than two kinds of maritime dangerous goods are loaded in same container should be approved by maritime authority before shipment. (IMDG Code (2014))The principle of approval mainly bases on such provisions, including table of segregation, dangerous goods list, chemical reaction and EmS, etc.

2) Current situation of implementation

For exported LCL dangerous goods, maritime authority adopts preliminary application system. Before packing container, shipper should provide Material Safety Data Sheet (MSDS) of dangerous goods within same container to maritime authority. Packing operation of container can only be carried out after approval of maritime authority, and shipment of LCL dangerous goods is prohibited without approval of maritime authority. (Cai & Li, 2006, PP.43-44)For imported LCL dangerous goods, packing certificate and dangerous goods manifest are required by maritime authority before ship alongside.

If any incompatible dangerous goods loaded in same container are found by maritime authority, for exported goods, re-packing operation is required before shipment, and for imported goods, the ship will be forbidden to enter into port unless the incompatible dangerous goods have been separated in different containers in anchorage or special safety measures have been taken to eliminate the potential risk to ensure the safety of port and facilities.

2.2.4 Administration against concealed or false declaration of dangerous goods

1) Law and regulation

Article 25 of Regulations on Administration of Prevention and Control of Pollution to the Marine Environment by Vessels stipulates that if maritime authority doubts that harmful polluting cargo carried by ships should be declared but not be declared or the information of declaration is no correct, he has the right to open the container and inspect cargo inside. (Regulations on Administration of Prevention and Control of Pollution to the Marine Environment by Vessels (2010))

2) Current situation of implementation

The most effective and direct method to judge whether there is a behavior of concealed or false declaration of dangerous goods mainly relies on the inspection of opening container to suspicious container. Due to limitation of manpower, material resource and time, container opening inspection can only focus on those containers with great suspicion. The inspection can be divided into three steps, the first step is to determine target container, the second step is to judge the nature of goods, and the last step is treatment of inspection result.

1. To determine target container. The selection of target container has many ways, including: 1).To determine target container through commodity name and other information of cargo manifest. 2). Based on past experience, to maintain high frequency inspection to the goods with high percentage of concealed or false declaration in the past, and cargo exporting to some developing countries where the inspection is not very strict therein. 3). Cargo of some shipping companies, owners, shippers and agents with bad reputation should be listed as key inspection object. 4). Containers reported by the public may carry dangerous goods without proper declaration. (Chen, 2007, P.24)

2. To judge the nature of goods. After selecting the target container, it needs open target container on site to judge whether the loaded goods are dangerous goods, which is key step. Normally, it needs sampling and testing of goods.
3. Treatment of inspection. If the test result shows that cargo in target container is general cargo, maritime authority should release the container at once and approve its application of shipment. But, if the test result demonstrates that it is dangerous goods without declaration, then, the authority would request the cargo owner to re-declare in terms of dangerous goods and impose corresponding punishment to the shippers.

2.3 Problems of regulatory system for maritime dangerous goods transport in China

Although domestic legislation of maritime dangerous goods have played positive role to protect property and safety of life at sea, there are still some problems in regulatory system of dangerous goods transport.

1) Legislation of maritime dangerous goods lacks systematization

Domestic legislations for carriage of maritime dangerous goods by ship mainly includes Maritime Traffic Safety Law and Port Law of the People's Republic of China issued by National People's Congress, and various decrees issued by Ministry of transport. In those laws and decrees, high-level laws are relevantly stable, and amendment and promulgation of low-level laws are quite frequent. Port Law of the People's Republic of China mainly focuses on the administration of dangerous goods within port. Although Maritime Traffic Safety Law of the People's Republic of China is important legal basis for maritime dangerous goods, it has not yet been modified since being promulgated in 1984, and only two provisions in law relate to maritime dangerous goods, which is far from enough to satisfy demand of safety supervision. However, low-level law such as decree may possess low legal force, which can't

become the main basis of administration for maritime dangerous goods. (Maritime Traffic Safety Law (1984))So it will produce the problem of law application.

2) **Overlapping areas of responsibility between various departments in laws**

The statutory responsibility of various departments to administrate maritime dangerous goods is dispersed in China, and those departments include maritime authority, environment protection department and port management department, etc. Because most domestic decrees are issued by various departments, there may exist overlapping area of responsibility between various departments in law, and may cause duplication or absence of administration for maritime dangerous goods.

3) Integration of domestic law with international legislation is not enough

IMDG Code is revised every two years, but most domestic laws relating to administration of maritime dangerous goods have not yet amended for more than 10 years in China. For example, List of dangerous goods in domestic laws was enacted on the basis of IMDG Code of Amdt 32-04 in 2005; however, the latest edition of IMDG Code is Amdt 37-14, which have added many new chemicals inside. Many dangerous goods listed in IMDG Code have been transported as general goods, which may cause great potential hazard for the public.

Chapter 3: Risk identification and evaluation of logistics chain of maritime dangerous goods

3.1 Analysis on classification and transport procedure of maritime dangerous goods

3.1.1 Property of goods

Maritime dangerous goods include dangerous goods in packaging forms and bulk dangerous goods. Dangerous goods are divided into classes 1-9 according to the hazard or the most predominant of the hazards they present. Some classes are also subdivided into divisions. These classes or divisions are shown as below (IMDG Code (2014)):

Class 1: Explosives

Division 1.1: substances and articles which have a mass explosion hazard

Division 1.2: substances and articles which have a projection hazard but not a mass explosion hazard

Division 1.3: substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard

Division 1.4: substances and articles which present no significant hazard

Division 1.5: very insensitive substances which have a mass explosion hazard

Division 1.6: extremely insensitive articles which do not have a mass explosion hazard

Class 2: Gases

Class 2.1: flammable gases

Class 2.2: non-flammable, non-toxic gases

Class 2.3: toxic gases

Class 3: Flammable liquids

Class 4: Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases

Class 4.1: flammable solids, self-reactive substances and solid desensitized explosives

Class 4.2: substances liable to spontaneous combustion

Class 4.3: substances which, in contact with water, emit flammable gases

Class 5: Oxidizing substances and organic peroxides

Class 5.1: oxidizing substances

Class 5.2: organic peroxides

Class 6: Toxic and infectious substances

Class 6.1: toxic substances

Class 6.2: infectious substances

Class 7: Radioactive material

Class 8: Corrosive substances

Class 9: Miscellaneous dangerous substances and articles

Figure 3-1: Labellings of dangerous goods

Source: IMDG Code Amdt. 37-14

3.1.2 Property of dangerous goods container

The danger degree of dangerous goods container mainly depends on dangerous goods inside. However, there are still some differences between property of dangerous goods container and property of dangerous goods itself. Dangerous goods container is roughly divided into two categories according to the structure and loading form. The first category is tanker, which mainly is suitable for loading the compressed or liquefied gas and flammable liquid, etc; the second category is general containers, which mainly apply to load substance of class1, and class 4-9. For the second

category of dangerous cargo containers, cargo cannot be stowed directly into container, before packing, in accordance with the relevant provisions and requirements of IMDG Code, cargo should be properly packaged (bags, bottles, buckets, wooden cases or in cartons). (Wang & Chen, 2009, P.18)Proper packaging and protection from container body are conducive to prevent dangerous goods in container from external strike, hit, and damage caused by human or machinery, so as to avoid or reduce the risk of leakage or damage of dangerous goods, and are also advantageous to segregation, heat insulation and waterproof of dangerous goods in container, and then to ensure the safety of dangerous goods in the process of handling, storage and transportation.

3.1.3 Requirements of dangerous goods transport

Shippers should provide to carriers with main physical and chemical nature and hazardous characteristics of dangerous goods, precaution and safety measures for transportation, handling operation and storage, personnel protective measures and emergency measures. Dangerous goods need proper packaging suitable for maritime transport, and adopt applicable outer packaging, inner packaging and dunnage materials according to actual need, so as to prevent damage of dangerous goods because of factors of climate, temperature, humidity, dynamic effect and pressure of stacking in the process of storage and transport. Each package should be carried out drop test, leakproofness test and stacking test in strict accordance with procedures established by the competent authority. Packages should also be marked with proper labellings and symbols that can reflect hazard of content, proper shipping name and necessary specification, etc. (Chen, 2009, PP.74-79) The structure of ship and its affiliate devices, such as electrical system, ventilation, fire control, fire detection, temperature detection, etc, should be suitable for shipment of dangerous goods.

3.1.4 Transport procedure of exported goods

Export procedure of general cargo container includes booking, acceptance of booking, empty container despatch, inland freight, customs clearance, cargo handling,

insurance, bill of lading and shipment, etc. Compared to transport of general cargo container, the procedure of dangerous goods container transport need also apply for dangerous goods packaging certificate from quarantine department and declare to maritime authority pre-shipment.

1) Transport procedure of general cargo

1. Booking. Consignors shall, in accordance with the provisions of the trade contract or letter of credit, within a certain amount of time before shipment, fill manifest and apply to booking from shipping company or its agents.
2. Acceptance of booking. Shipping company decides whether to accept application of booking from consignor according to category and weight of cargo, shipping route and transport time, etc. Once accepting the booking, shipping company should make cargo manifest and send it to container yard and container freight station, then, consignor can despatch empty container and deliver cargo.
3. Empty container despatch. Usually, the consignor picks up empty container in container yard in case of FCL, and picks up empty container in container freight station in case of LCL.
4. Packing of LCL. Container freight station is in charge of packing of LCL according to booking information.
5. Delivery of FCL. Consignor shall be responsible for packing container and sealing container with custom seal, and transport it to container terminal yard through inland freight. The yard should verify the dock receipt and packing list.
6. Endorsement of delivery. The terminal yard should sign and endorse on dock receipt after receiving container and return to consignor.
7. Bill of lading. Consignor exchanges bill of lading from shipping company with dock receipt signed by terminal yard.
8. Shipment. Shipping company makes loading plan and loads the container after ship alongside.

(Liang, 2006, PP.30-31)

2) Transport procedure of dangerous goods

The transport procedure of dangerous goods is same with general cargo except declaration of dangerous goods. For FCL container, consignor is responsible for packing container under the supervision of packing inspector. After completing packing container, the packing inspector would sign packing certificate for consignor, and then consignor can declare to maritime authority with signed packing certificate. For LCL container, container freight station is in charge of packing container, and should declare all dangerous goods that will be loaded in the same container to maritime authority before packing.

Any wrong at any link in the process of transport, no matter intentional or unintentional, will cause great potential safety hazard, especially for dangerous goods. Because container is closed, and all information relating to cargo circulates through documentation, even the carriers also don't ensure whether cargo in container is in line with documentation. Related parties of dangerous goods transport include carries, shipper, container freight station, terminal yard and consignee, etc. Among them, the carrier and shipper play largest impact on safety of dangerous goods transport.

3.2 Risk identification of maritime dangerous goods in container

Risk assessment of maritime dangerous goods in container needs to research on container itself and surrounding environment, to collect relevant data, to analyze and identify all kinds of risk factors in the region and to evaluate the consequence of all kinds of risk factors, and then risk degree of each risk factor can be obtained. The quantitative analysis of risk for maritime dangerous goods can be carried out from the following aspects.

3.2.1 Nature of dangerous goods

Dangerous goods possess such characteristics of explosion, inflammability, toxicity, corrosion, radioactivity, etc. (Maritime Traffic Safety Law (1984)). According to regulation of IMDG Code, dangerous goods are divided into 9 kinds of class according to the hazard or the most predominant of the hazards they present. (IMDG Code (2014)) Potential risk of dangerous goods can be understood from the nature of the dangerous goods, including flash point, melting point, boiling point, ignition point, explosion limit, transportation index, content of poison and classification, etc. Many dangerous goods not only have main risk, but present subsidiary risk. The extent of potential threats to marine environment and transport limitation of dangerous goods are all important basis to understand the risk degree of dangerous goods.

3.2.2 Packaging of dangerous goods

Packaging of dangerous goods can be divided into general packaging and special packaging, and some special dangerous goods must use special packaging. Dangerous goods other than those of classes 1, 2, 5.2, 6.2 and 7, and other than self-reactive substances of class 4.1 are divided into three packing groups in terms of the degree of danger they present. (IMDG Code (2014)) If certain dangerous goods use higher level packaging group for packaging, it will reduce transport risk at a certain extent; on the contrary, if lower level packaging group for packaging is used, it will increase risk and become a potential hazard.

Container that has previously loaded dangerous goods should be still regarded as dangerous goods container unless steps such as cleaning, purging of vapors or refilling with a non-dangerous substance are taken to nullify hazard. (Chen, 2009, P.89)

3.2.3 Stowage of dangerous goods in container

Stowage of dangerous goods in container includes stacking, lashing, segregation and dunnage, etc. In practice, the stowage of dangerous goods may possess the following problems due to negligence or fault of packing staffs:

1. Stacking of cargo in container is not correct
2. Lashing of cargo is not solid
3. Packages of cargo are not effectively padded
4. Segregation of various dangerous goods does not meet the requirement of IMDG Code
5. Overweight of upper cargo may lead to damage or leakage of cargo at the bottom in container
6. Weight of cargo exceeds the maximum gross weight of container

(Safety specification for the packing of dangerous cargo into container by marine transport (2007))

In the process of navigation, the above problems may lead to collapse, collision, friction, rolling and extrusion of goods inside, and even cause damage to packages and containers. The transport risk of dangerous goods will suddenly increase.

3.2.4 Container

Container used for carrying dangerous goods should meet the following basic requirements: (CCS, 2008, p.20)

1. Comply with the ISO standards;
2. Four posts, six sides, and eight corners are intact;
3. Welding parts are firm;
4. Container inside is clean, dry and tasteless;
5. No leakage and no light-leaking;
6. Owning inspection certificate of R.O.

In addition, the container packing dangerous goods should not have deformation or damage. The packages of cargo should not have damage or leakage, and each side of container should be posted dangerous goods markings. If the material, structure and markings of container do not meet the above requirement, then the transport risk of container will increase.

3.2.5 Stowage and segregation of container on board

Stowage of dangerous goods containers on board should comply with regulation of IMDG Code strictly. There are 15 kinds of special stowage category in IMDG Code for explosives. Except explosives, the stowage category of other dangerous goods is divided into 5 kinds, including A, B, C, D and E. The stowage of dangerous goods on board should follow the general principle and specific requirements. Document of Compliance with Special Requirements for Carrying Dangerous Goods should clearly list the classification of various dangerous goods that can be allowed to load in cargo hold or on deck. In addition, special requirements of some goods should also be endorsed on it. (IMDG Code (2014))

In the aspect of segregation of dangerous goods, the segregation of various dangerous goods except explosives normally abides by segregation table (see Appendix A). Other than general provisions of segregation, dangerous goods list in IMDG Code chapter 3 has some particular provisions for segregation, if general provisions of segregation conflicts with particular provisions, then particular provisions take precedence over general provisions. In addition, if certain dangerous goods have one subsidiary risk, and subsidiary risk is more stringent than primary hazard, then the segregation should apply to secondary hazard. For segregation of explosives (see Appendix B), there are 13 kinds of compatibility group. Unless mixed stowage is permitted for explosives, for closed container, the segregation of various explosives must separate from each other at least one transport unit. (Wang & Chen, 2011, P.22)

3.2.6 Other factors

Safety of dangerous goods transport is closely related to environment factor, and such factors should also be taken into consideration for stowage of dangerous goods in container, including hull structure of ship, equipment performance, weather condition and ventilation, etc. In addition, accident is another risk for dangerous goods transport. For example, container drops into sea caused by bad weather or strong wave.

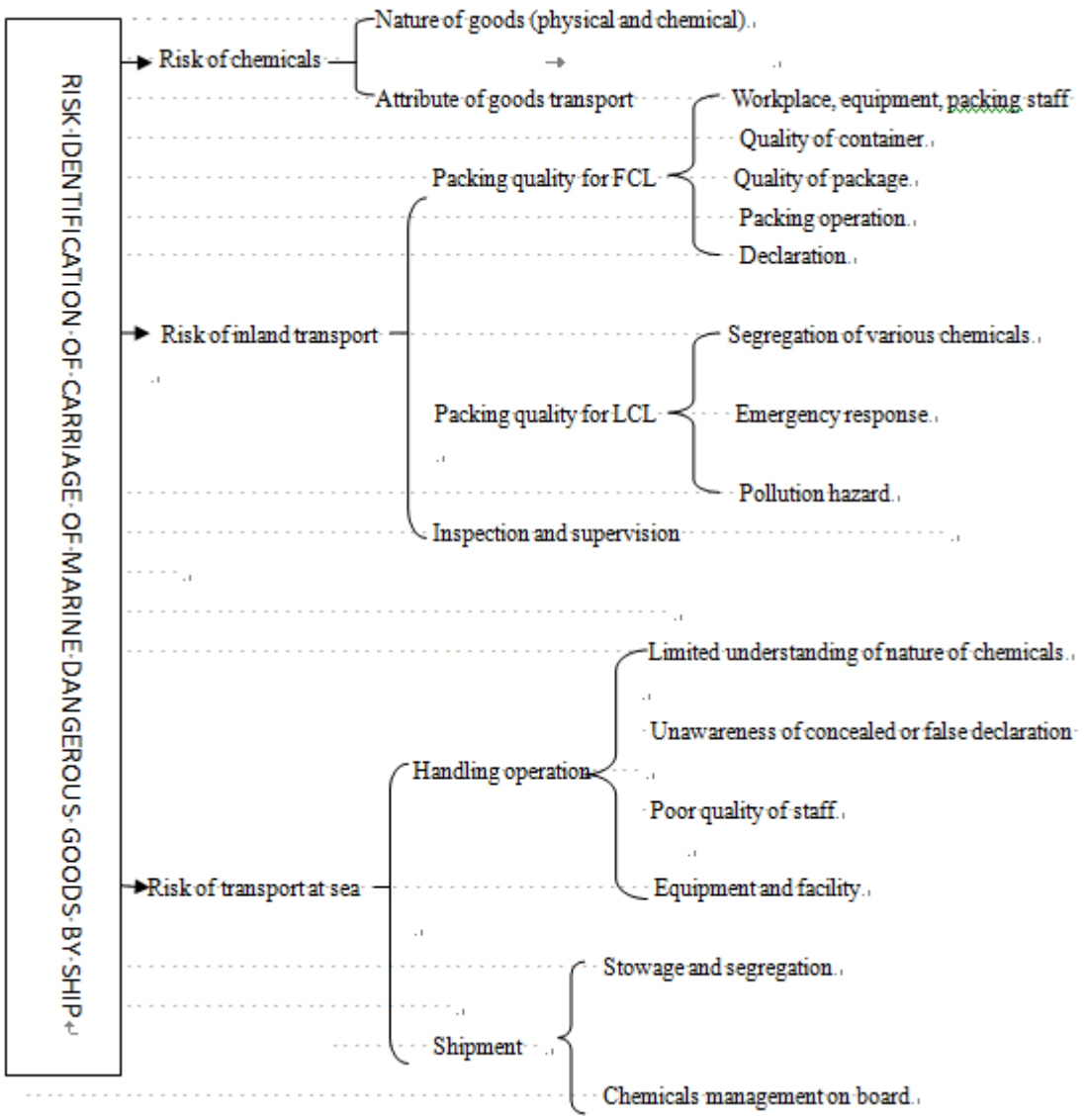

Diagram 3-2: Risk identification of carriage of maritime dangerous goods by ship

Source: author

3.3 Risk identification of inland transport of maritime dangerous goods

3.3.1 Risk identification of packing for FCL

Dangerous goods transport is a high risk activity. If the stowage of dangerous goods is not stowed in accordance with the requirements of IMDG Code, once accident happening, it may cause serious consequence, such as explosion, fire, or serious

pollution, etc. As the upstream of maritime dangerous goods transport, inland transport link is also very important. Two steps of packaging and packing container of dangerous goods may possess many potential safety hazards in such links, including: packing station, safety protection of packing staff, handling devices, safety of container, lashing of packages, mixed packing, and declaration of dangerous goods.

1) Risk of packing station

Packing operation of dangerous goods should be carried out in special packing station, which should avoid direct sunlight, isolate heat, and keep away from fire, meanwhile it should have enough areas and equips sufficient fire fight equipments. Once accident occurs, it can be disposed effectively. (Miao & Xiao, 2013, P.26)

2) Safety protection of packing staff

Packing staff should wear necessary protective devices during operation, including wearing protective work clothes, protective masks and rubber gloves, etc. During packing inflammable or explosive dangerous goods, packing staff is prohibited to wear iron palm shoes, iron spike shoes and overalls that are easy to produce static electricity. During packing toxic goods, packing staffs are forbidden to eat until they have changed clothes and washed whole body. (Safety specification for the packing of dangerous cargo into container by marine transport (2007))

3) Devices of packing container

During packing inflammable and explosive dangerous goods, it should use explosion-proof electrical equipments and anti-spark tools, and specialists should be responsible for monitoring packing on-site. During packing explosives, organic peroxides, toxic gases and toxic substances with packaging group I, the power of packing machineries should be used less than 25% of rated load.(Safety specification

for the packing of dangerous cargo into container by marine transport (2007)) All machinery packing devices should be equipped with Mars extinguishing device.

4) Safety of container

Strength and structure of container should be inspected carefully before packing to prevent usage of unsatisfactory containers. Packing staff should also understand the characteristic of dangerous goods, measures to prevent accident and emergency measures after accident. Before packing explosives and oxidizing substances, container should be cleaned to prevent remaining of dust, debris and other impurities in container, so as not to cause fire or explosion. Any part of packages should not be prominent beyond container, and the door can be closed smoothly after packing. Some dangerous goods packaged in paper bags, fiber board and fiber drums will cause spontaneous combustion reaction, heat or produce poisonous gas when exposed to water, so strict examination of waterproof for container is quite essential.

5) Packaging of maritime dangerous goods

Maritime dangerous goods can only been packed in container and transported by sea after proper packaging according to requirements of IMDG Code. Liquefied gas and compressed gas should only be packed in gas container that conforms to the provisions of IMDG Code. In addition, some dry bulk dangerous goods can be packed in bulk container. Packaging of dangerous goods is divided into general packaging and special packaging. Some dangerous goods must use special packaging, such substance of class 2, class 7 and parts of explosives. General packaging and parts of special packaging are divided into three packaging groups according to danger degree of dangerous goods. If packaging group of dangerous goods is not used correctly, or packaging quality does not meet the requirement of IMDG Code, it will increase transport risk of dangerous goods and become a safety loophole.

6) Mixed packing of dangerous goods in container

It should try to avoid stowing various dangerous goods with different packaging group into the same container. Incompatible dangerous goods should not be stowed in the same container. In addition, when dangerous goods are stowed with general cargos in a container, the dangerous goods should be stowed close to door in order to be taken out easily in case of danger. The relevant information of dangerous goods should be in line with transport documentation, and the packaging and labellings and symbols should be intact.

7) Lashing of dangerous goods

Stowage of dangerous goods in container includes stacking, segregation, dunnage and lashing, etc. In practice, due to the negligence of packing staff, there are some problems directly affecting transport risk of dangerous goods. For example, stacking of cargo in container is not correct; lashing of cargo is not tight; dunnage of cargo is not reasonable; segregation does not meet the requirement, and heavier cargo is stowed on lighter cargo, and so on. In the process of navigation at sea, due to trim or list of ship, the activities of collapse, collision, friction, rolling, extrusion and mutual influence between goods may cause damage to packages and container, and even cause accident, such as leakage, fire and explosion.

Considering the movement factors of cargo in container in the process of navigation at sea, cargo in container should be well lashed to prevent movement. The materials used for lashing dangerous goods should be paid attention to fire safety requirements and has enough strength, and can eliminate various stress caused by change in traffic acceleration. Lashing materials mainly include cable, fiber cable, steel belt, nylon belt and bag, etc. The fastener for lashing should have fixed fastening device, and after lashing, all fasteners should be in a fixed position, in order to prevent to make the fasteners loose and lower lashing effect due to factors of vibration or swing in the process of transport. The filling pressure given by manufacturers should be strictly

observed for usage of air bag. (Yu, 2010, P.14)The internal temperature of container will rise as change of external temperature, so allowance of container should be maintained during packing.

8) Declaration of dangerous goods

The biggest risk in dangerous goods declaration is concealed and false declaration. The consignor or his agents may conceal dangerous goods out of interest, or other subjective and objective reasons. Some carriers don't establish strict corresponding preventive procedures and examination mechanism for dangerous goods during booking and don't verify booking documentation carefully, so some dangerous goods may be transported regarded as general cargo without declaration. The shipper should declare in booking note that the consigned dangerous goods have been properly packed, labeled and marked, in addition, the note should also indicate proper shipping name and classification of dangerous goods, and so on. (Chen, 2009, P.88)

The packing inspector responsible for dangerous goods packing should fill and sign for packing certification to prove that dangerous goods have been properly packed and comply with the relevant provisions of IMDG Code.

3.3.2 Risk identification of packing for LCL

For LCL, normally packing operation is carried out in cargo freight station, including packing operation of dangerous goods with general cargo and packing operation of various dangerous goods. Packing operation for LCL has a great risk. Mixed packing of general cargo with single dangerous goods should be paid attention to the nature of dangerous goods. And mixed packing of various dangerous goods should also be paid special attention to compatibility. Mutual incompatible dangerous goods are prohibited to be stowed in the same container. (Bao, 2007, P.34)

1) Safety risk of dangerous goods LCL

Dangerous goods LCL should consider the safety risk and comply with provisions of segregation. Incompatible dangerous goods can't be stowed in a container, and some special dangerous goods can't be stowed with such substance that would contribute its danger. In addition, inflammable cargo can't be stowed with such substance that would be explosive in contact with fire.

2) Risk of emergency response

Dangerous goods LCL must consider emergency response after accident, and comply with the following principle of stowage: 1. Nature of various dangerous goods is similar, but the fire fighting method is different, those chemicals can't be stowed in a container. 2. Dangerous goods have similar nature, but hazard of dangerous goods is very high, and it is not easy to put out fire and rescue cargo after accident, those chemicals can't be stowed in a container.

3) Risk of pollution

Dangerous goods LCL should not only consider the safety hazard, but consider the pollution hazard, including indirect harm for cargo and direct harm to quality of goods.

3.3.3 Risk identification of packaging inspection and testing of dangerous goods

The quality inspection link in the process of production and packaging inspection of dangerous goods should be in strict accordance with the ISO quality management system requirements, to ensure that dangerous goods will not give rise to safety problem of leakage, deformation and deterioration during transport after testing and certification from competent authority or third party inspection agency, and to ensure best safety performance of dangerous goods. Especially for explosives, it must ensure

the essential safety of goods, to avoid explosion due to friction between cargos during voyage. Packaging material is also need to be inspected to prevent from using inferior packaging materials for dangerous goods. (Chen, 2009, PP.70-72)

However, in practice, few inspectors may carry out false inspection for production, packaging and packing of dangerous goods because of economic interest, negligence of work, or poor work ability, and issue false inspection report, which may give rise to a series of subsequent risk. Packing inspectors as professional staffs approved and certified by maritime authority are responsible for packing supervision of dangerous goods on-site. They need undertake a large number of packing operations, and huge workload may lead to heavy burden for inspectors, causing some ineffective inspection. Such behaviors will lead to huge potential risk for dangerous cargo at the beginning of logistic chain.

3.4 Risk identification of dangerous goods transport during voyage

3.4.1 Risk identification of terminal handling of dangerous goods

Due to hazard of dangerous goods, in the process of handling operation at terminal, most accidents may be caused because of the following reasons：

1. If packaging quality of dangerous goods (such as material, strength and sealing performance) could not reach the requirements of standards, it may cause damage to packages in container in the process of transport, handling and storage, or leakage due to lax seal of packages. If the leakage is non-powder solid dangerous goods, because the leakage is still in container, as long as it does not contact with such substances that would conflict with each other and cause chemical reaction, it may have little effect on safety of dangerous goods transport. But if the leakage is combustible gas, liquid or powder solid dangerous goods, under certain condition, it may cause accident such as fire, explosion, or poisoning, etc. If the leakage is Flammable solids substances liable to spontaneous combustion, substances which, in contact with water, emit flammable gases, oxidizing substances or organic peroxides, under the condition of external high temperature, strong vibration or

rainfall, it may cause fire in container. If Leakage is a toxic substance, especially highly toxic substances, it may cause poisoning of operators. If leakage is corrosive liquid, it may cause severe corrosion to container and cargo inside or outside, even cause accident such as fire, explosion, or chemical burns. (Chen, 2004, P.8)

2. Port enterprises don't fully know the actual condition of goods in container due to closure of container, which would bring certain potential risk for handling operation of dangerous goods. Handling operation of dangerous goods at terminal need take special safety measures, especially for tanker. The outstanding characteristics of tanker are high pressure, low temperature and large capacity. If tanks or its affiliated equipment (such as valve, safety valve, pressure gauge, etc.) appear crack, damage or failure, it will lead to leakage of flammable, explosive, toxic substances in tanker. (Feng, 2009, PP.31-32)Once leaking, it is likely to cause severe accidents such as fire, explosion or poisoning, and the consequences would be rather serious.

3. Handling devices such as bridge cranes, hoists tire, forklift, lifting machines and other equipments having quality defects or break down during operation, it may cause dropping or overturn of container, and may result in leakage or damage of dangerous goods. If bridge cranes, hoists tire, forklift driver is not in strict accordance with the safety operation procedures to handle dangerous goods container, containers may drop or collide with other containers stowed on board or in container yard in the process of lifting or movement, thus causing leakage or damage of dangerous goods, even resulting in fire or explosion accident directly.

4. When truck is drived exceeding limited speed within the port area, container may drop from truck at sharp turn or roll over with truck, resulting in damage or leakage of dangerous goods. Because a few truck drivers may be not familiar with driving direction or fatigue driving, the truck carrying dangerous goods may

collide with other trucks or containers stowed in container yard, leading to damage or leakage of dangerous goods. In addition, if road in port is rough, slippery, and lacks necessary road traffic signal, trucks may encounter turbulence or sharp turn during driving, and resulting in damage of package in container, even falling of container. In summer, high temperature may cause packages in container (cylinders, cans, bucket) crack due to thermal expansion, causing leakage or other accidents. The typhoon, or sudden strong gust of wind hitting on every front of dangerous goods containers, may cause falling of containers stowed in container yard, resulting in damage of dangerous goods.

5. Many terminal operators are temporary workers, who possess poor safety knowledge, safety skills and safety awareness. In addition, fast fluidity of terminal operators also affects improvement of their working skills and operation skills. During terminal operation, cooperation between various departments may be not coordinated, or overall consciousness of field management may also be weak due to poor safety education and training. So, various accidents caused by human factors are quite outstanding in the process of operation.

3.4.2 Risk identification of dangerous goods transport at sea

During transport at sea, ship is affected by strong vibration, large variation of the temperature and humidity in a short period of time and bad weather, etc, so dangerous goods, especially some chemicals requiring temperature control will face huge risk. In addition, some unexpected accidents during voyage, such as dangerous goods container crashing into sea because of bad weather, or container damage due to collision with other ships, are all risk factors that should be focused on. Some captains and crews don’t slow down sailing speed or change planned course under the pressure of schedule or economical interest from shipping company even though encountering heavy weather, causing dropping of containers stowed on deck into sea. At present, some ultra large container ships are designed to stow 7 layer containers on deck in

response to the pressure from continuous rising of oil prices and port fee, to improve its competitiveness in shipping market, but deck lashing equipments have no substantial improvement, which objectively increases probability of accident of container shifting, collapse and dropping into sea. (Bao, 2007, PP.33-34) Long-term lacking of inspection and maintenance for lashing devices may also left hidden danger for transport safety of container during voyage. Some shippers don't lash goods in container properly where stacking of packages leaves a large vacancy in order to save dunnage and lashing fee, causing goods in container movement and collapse, even breaking through container and endangering adjacent containers. In addition, stowage of dangerous goods container violates stowage principle that light container should be loaded on heavy container, causing container collapse due to lacking of stability. Incorrect segregation between various dangerous goods containers will also increase transport risk of dangerous goods.

Chapter 4: Risk analysis and assessment of maritime dangerous goods transport

4.1 FTA analysis of transport risk for maritime dangerous goods

Firstly, it should try to widely collect past accident cases and related accident statistics of maritime dangerous goods, and investigate related accident reasons. Secondly it should clearly understand the system of dangerous goods transport, including workflow, characteristics of container and dangerous goods, practitioners, working place, working environment and related laws and regulations, etc, and then to determine the top event. Top event is object event, namely dangerous goods accident. Finally, it should determine the relevant factors that affect safety of dangerous goods.

According to accident causation theory of Heinrich, author believe that management defect including management defect of container yard, freight station, shipping company and maritime authority, is the root cause of dangerous goods accidents, which produces quality defects of practitioners and crews, unseaworthiness of

dangerous goods and adverse environment of dangerous goods during production, operation and transportation, and then causes unsafe behaviors of practitioners and crews, unsafe state of container and dangerous goods and adverse environment of unsafe production, operation and transport, and finally produces the initial accident danger. (Wang, 2009, PP.43-45) If the accident danger fails to be detected or proper emergency remedial measures are used, it will result in a serious accident finally.

Through investigation of dangerous goods accident case, investigators should analyze type of dangerous goods, time, place and environment that are prone to accident and remedial measures after accident, and list all the direct and indirect reasons of accidents, such as poor management, poor ability of practitioners, imperfect handling devices, unreasonable stowage and segregation, poor quality of dangerous goods packaging and adverse environmental, etc.

After establishment of dangerous goods fault tree, the minimum cut set can be obtained through logical relation and logic operation, and through qualitative analysis of the fault tree structure, finally the important degree of each basic event and weak link of system can be determined, and then the safety system of dangerous goods transport can be evaluated.

Through above analysis of risk identification of dangerous goods in Chapter 3, dangerous goods fault tree can be established as shown in figure 4-1. The minimal radius set connects with top event by OR gates (), and the less minimal radius set is, much safer it becomes. Basic event in minimal radius set connects with next event with OR gates, so the less basic events in radius set is, the safer it will be, and radius set with more basic events is the weak link of system. (Wang, 2009, PP.43-45)

After combing risk source of dangerous goods transport, it can sort out 35 basic events. Because the importance of basic events is different, arrangement of basic events structure can be obtained by minimal cut set, and according to their properties, 32 basic events finally can be concentrated to 15 basic events reflecting transport risk of dangerous goods, including: ship (sailing route, shipping companies, ship, weather conditions during voyage) and cargo (seasonal factors, types of goods, shipping name ,

packaging of goods, shape of goods, cargo inspection institutions, packaging inspection institutions), third-party logistics service providers (container transport company, shipping agent, container packing agency, freight forwarding company and booking party).

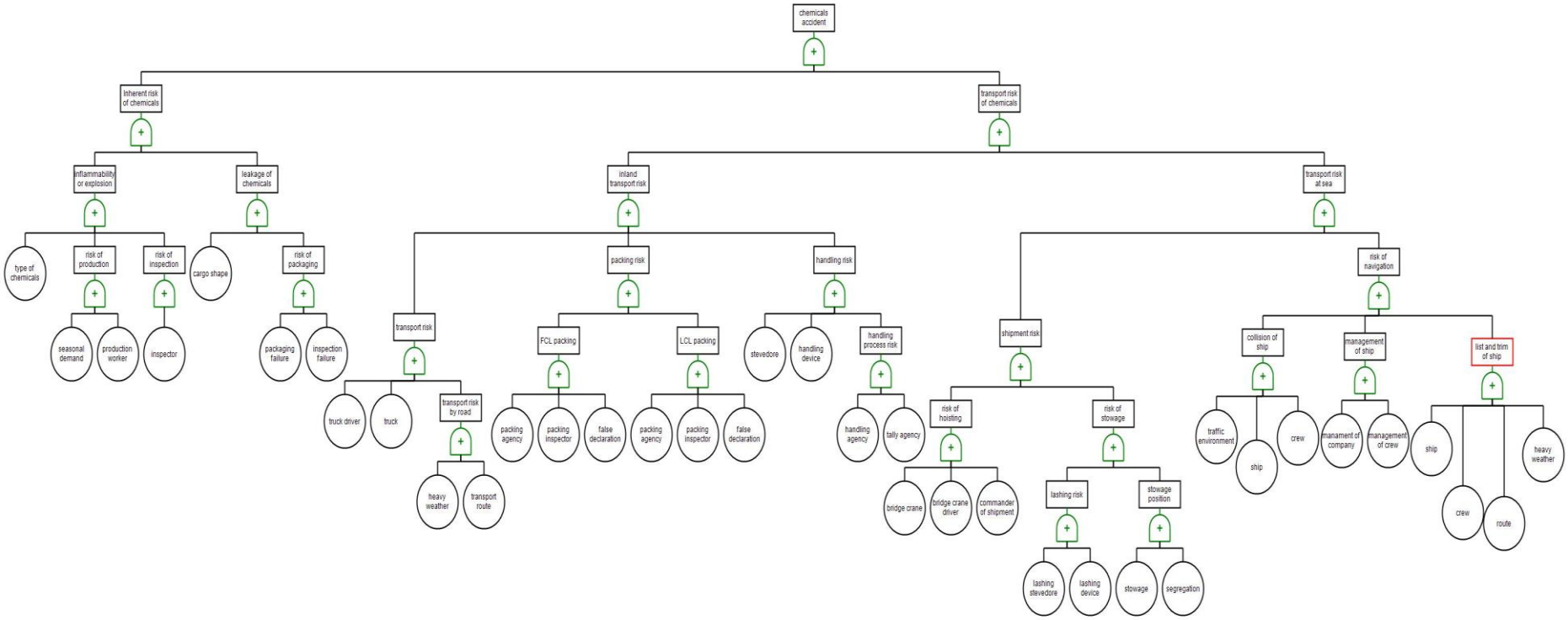

Figure 4-1: Dangerous goods fault tree

Source: Wang, S. F. (2009). Analysis on Safe Countermeasures to Dangerous Goods Container Based on Fault Tree Analysis. China Water Transport, 2009(06), 1006-7973.

4.2 Risk attribute of dangerous goods transport

Risk attribute refers to the degree of attention for safety inspection of dangerous goods and risk degree itself.

Firstly, to determine the risk weight of dangerous goods container according to risk attribute, and to set up a specific standard value, when risk weights reach or exceed the standard value, the container will be integrated into the inspection system. In order to determine the risk value, the form of "yes" and "no" will be used for distinction. Risk value is defined as "0" for low risk dangerous goods container; correspondingly, risk value of high risk dangerous goods container is more than "0". (Ren & Wu, 2006, PP.126-128)For high risk dangerous goods container, normally, there exists different risk levels and needs a detailed risk classification management.

In order to reduce time cost and economic cost when maritime authority officers select suspected dangerous goods container for inspection, high risk value is divided into "1" and "2", which correspond to the degree of attention in selecting suspected container for safety inspection respectively. (Ren & Wu, 2006, PP.126-128) For example, risk value should be set as "2" for those companies such as shipping company and freight forwarding agency, which have concealed dangerous goods in the past. Risk index of dangerous goods transport and its risk attribute are shown in the following table:

Parameter		**Risk attribute**		
		High risk container (HRC) (sum of risk weight>=4)		**Low risk container(LRC)**
		Standard	**weight**	**Standard**
Ship	Route(destination port)	Southeast Asian countries, South America	2	Other countries
		Africa	1	
	Shipping company	Dangerous goods accidents caused by poor safety management in the	1	No dangerous goods accident

		past		
	Ship	Deficiency relating to dangerous goods has been found in last PSC OR FSC inspection	2	No relevant deficiency
	Weather condition during voyage	Heavy weather (storm, typhoon, or poor visibility)	1	Other
Goods	Type of goods	Flammable, explosive and toxic goods	2	Other goods
		Corrosive goods	2	
		Miscellaneous dangerous substances and articles and environmentally hazardous substances	1	
	Name of goods	Cargo name used for concealed or false declaration in the past	2	Other cargo name
	Packaging of goods	Bottle or barrels, woven bag and box	1	Other packaging
		Overweight of packaging unit	1	On overweight
	Shape of goods	Gas, liquid	1	Other
	Cargo inspection agency	Wrong inspection occurred in the past	1	No mistake
	Packaging inspection agency	Wrong inspection occurred in the past	1	No mistake
Third-party logistics provider	Container transport agency	Container damage occurred in the past	1	No damage happened
	Shipping agency	Concealed or false declaration occurred	2	Normal

		in the past		
	Packing agency	Dunnage material or lashing is not proper, or container overweight	1	Other
	Freight forwarding agency	Concealed or false declaration occurred in the past	2	Normal

Figure 4-2: Risk index of dangerous goods transport and its risk attribute table

Source: author

There are 15 parameters in the risk index, and total risk weight is 25 points. If risk weight greater than or equaling to 4 points is assumed as high risk, then such containers with risk weight more than 4 points will be treated as key object of safety inspection by maritime authority.

Chapter 5: Summary and Conclusion

Risk identification and assessment on carriage of maritime dangerous goods by ship is a complex program, which involves many links, including production, packaging, packing, transportation, handling, storage, and shipment of dangerous goods, etc. The paper discusses and analyzes existing problems of safety management of maritime authority on maritime dangerous goods through comparative study of current regulatory mode and relevant mechanism in China and at abroad. Through the analysis of logistics chain of maritime dangerous goods, author uses quantitative approach to identify the risk of each link in the process of transport and assesses the main risks. According to the analysis of above chapters, the following conclusions can be obtained, including:

1. At present, there are many problems on dangerous goods transport in China, such as improper packaging of cargo, concealed and false declaration, etc. It also has many problems on legislation, such as amendment of laws not in time and responsibility overlapping between various departments, etc. Such problems can be solved through drawing lessons from advanced safety management experience

of developed counties on maritime dangerous goods, especially, legislative experience of the USA and the EU.

2. Risk of carriage of maritime dangerous goods by ship have diverse features, involving 15 elements of 3 categories, which is risk factor of ship, cargo and third-party logistics service provider.
3. Through strengthening source and process control of maritime dangerous goods, the maritime authorities can establish suspected dangerous goods container selection system by dynamic risk assessment and registration system of dangerous goods.
4. Enterprise is the main responsibility body to undertake safety production of maritime dangerous goods. Maritime authority should cooperate with third-party service provider to reinforce safety supervision of dangerous goods.
5. To perfect legislation of maritime dangerous goods, in order to clear responsibility of various departments, and avoid duplication or absence of governance to dangerous goods.
6. Maritime dangerous goods are characterized with the nature of being international, professional and technical. Emergency response to maritime dangerous goods accident needs cooperation and coordination of various departments with relatively complex procedure, including reporting procedure, risk assessment of accident, establishing emergency response plan, implementation of emergency plan and summary and evaluation of accident.
7. Because dangerous goods transport is professional and hazardous, it is necessary to train and certify for practitioners who engage in maritime dangerous goods business, so as to ensure safety of maritime dangerous goods at each link of logistics chain.

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APPEDIX A: Segregation table

CLASS		1.11.2 1.5	1.3 1.6	1.4	2.1	2.2	2.3	3	4.1	4.2	4.3	5.1	5.2	6.1	6.2	7	8	9
Explosives	1.1, 1.2, 1.5	*	*	*	4	2	2	4	4	4	4	4	4	2	4	2	4	X
Explosives	1.3, 1.6	*	*	*	4	2	2	4	3	3	4	4	4	2	4	2	2	X
Explosives	1.4	*	*	*	2	1	1	2	2	2	2	2	2	X	4	2	2	X
Flammable gases	2.1	4	4	2	X	X	X	2	1	2	X	2	2	X	4	2	1	X
Non-toxic, non-flammable gases	2.2	2	2	1	X	X	X	1	X	1	X	X	1	X	2	1	X	X
Toxic gases	2.3	2	2	1	X	X	X	2	X	2	X	X	2	X	2	1	X	X
Flammable liquids	3	4	4	2	2	1	2	X	X	2	1	2	2	X	3	2	X	X
Flammable solids (including self-reactive substances and solid desensitized explosives)	4.1	4	3	2	1	X	X	X	X	1	X	1	2	X	3	2	1	X
Substances liable to spontaneous combustion	4.2	4	3	2	2	1	2	2	1	X	1	2	2	1	3	2	1	X

CLASS		1.11.2 1.5	1.3 1.6	1.4	2.1	2.2	2.3	3	4.1	4.2	4.3	5.1	5.2	6.1	6.2	7	8	9
Substances which, in contact with water, emit flammable gases	4.3	4	4	2	X	X	X	1	X	1	X	2	2	X	2	2	1	X
Oxidizing substances (agents)	5.1	4	4	2	2	X	X	2	1	2	2	X	2	1	3	1	2	X
Organic peroxides	5.2	4	4	2	2	1	2	2	2	2	2	2	X	1	3	2	2	X
Toxic substances	6.1	2	2	X	X	X	X	X	X	1	X	1	1	X	1	X	X	X
Infectious substances	6.2	4	4	4	4	2	2	3	3	3	2	3	3	1	X	3	3	X
Radioactive material	7	2	2	2	2	1	1	2	2	2	2	1	2	X	3	X	2	X
Corrosive substances	8	4	2	2	1	X	X	X	1	1	1	2	2	X	3	2	X	X
Miscellaneous dangerous substances and articles	9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Numbers and symbols relate to the following terms as defined in this chapter:

1 - "Away from"
2 - "Separated from"
3 - "Separated by a complete compartment or hold from"
4 - "Separated longitudinally by an intervening complete compartment or hold from"
X - The segregation, if any, is shown in the Dangerous Goods List
* - See 7.2.7.2 of this chapter.

Source: IMDG Code Amdt. 37-14

APPENDIX B: Table of segregation of freight containers on board container ships

SEGREGATION REQUIREMENT	VERTICAL			HORIZONTAL							
	CLOSED VERSUS CLOSED	CLOSED VERSUS OPEN	OPEN VERSUS OPEN		CLOSED VERSUS CLOSED		CLOSED VERSUS OPEN		OPEN VERSUS OPEN	
					ON DECK	UNDER DECK	ON DECK	UNDER DECK	ON DECK	UNDER DECK
"AWAY FROM" .1	ONE ON TOP OF THE OTHER PERMITTED	OPEN ON TOP OF CLOSED PERMITTED OTHERWISE AS FOR "OPEN VERSUS OPEN"	*NOT* IN THE SAME VERTICAL LINE *UNLESS* SEGREGATED BY A DECK	FORE AND AFT	NO RESTRICTION	NO RESTRICTION	NO RESTRICTION	NO RESTRICTION	*ONE* CONTAINER SPACE	*ONE* CONTAINER SPACE OR *ONE* BULKHEAD
				ATHWART-SHIPS	NO RESTRICTION	NO RESTRICTION	NO RESTRICTION	NO RESTRICTION	*ONE* CONTAINER SPACE	*ONE* CONTAINER SPACE
"SEPARATED FROM" .2	*NOT* IN THE SAME VERTICAL LINE *UNLESS* SEGREGATED BY A DECK	AS FOR "OPEN VERSUS OPEN"		FORE AND AFT	*ONE* CONTAINER SPACE	*ONE* CONTAINER SPACE OR *ONE* BULKHEAD	*ONE* CONTAINER SPACE	*ONE* CONTAINER SPACE OR *ONE* BULKHEAD	*ONE* CONTAINER SPACE	*ONE* BULKHEAD
				ATHWART-SHIPS	*ONE* CONTAINER SPACE	*ONE* CONTAINER SPACE	*ONE* CONTAINER SPACE	*TWO* CONTAINER SPACES	*TWO* CONTAINER SPACES	*ONE* BULKHEAD
"SEPARATED BY A COMPLETE COMPARTMENT OR HOLD FROM" .3				FORE AND AFT	*ONE* CONTAINER SPACE	*ONE* BULKHEAD	*ONE* CONTAINER SPACE	*ONE* BULKHEAD	*TWO* CONTAINER SPACES	*TWO* BULKHEADS
				ATHWART-SHIPS	*TWO* CONTAINER SPACES	*ONE* BULKHEAD	*TWO* CONTAINER SPACES	*ONE* BULKHEAD	*THREE* CONTAINER SPACES	*TWO* BULKHEADS
"SEPARATED LONGITUDINALLY BY AN INTERVENING COMPLETE COMPARTMENT OR HOLD FROM" .4	PROHIBITED			FORE AND AFT	MINIMUM HORIZONTAL DISTANCE OF 24 M	*ONE* BULKHEAD *AND* MINIMUM HORIZONTAL DISTANCE OF 24 M*	MINIMUM HORIZONTAL DISTANCE OF 24 M	*TWO* BULKHEADS	MINIMUM HORIZONTAL DISTANCE OF 24 M	*TWO* BULKHEADS
				ATHWART-SHIPS	PROHIBITED	PROHIBITED	PROHIBITED	PROHIBITED	PROHIBITED	PROHIBITED

* CONTAINERS NOT LESS THAN 6 M FROM INTERVENING BULKHEAD.

NOTE: ALL BULKHEADS AND DECKS SHALL BE RESISTANT TO FIRE AND LIQUID.

Source: IMDG Code Amdt. 37-14