Reducing the Risk of Chemical Dangerous Goods Transport by Road in China and Preventing Relevant Accidents

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Abstract

Nowadays the petroleum and chemical industry in China has experienced a growing stage, where the scale of production in the industry has expanded as well. The demand of the chemical dangerous goods transport is thereby growing, leading to the increase of the risk of the overall logistic market. In order to reduce the risk through transporting and improve the safety level of the industry, the potential causes of these accidents were investigated and analyzed, which could be summarized from organization, human, vehicle and environment aspects, based on a risk assessment and other relevant theories. Moreover, with the establishment of Regulations Concerning Road Transportation of Dangerous Goods in 2018, official industry standards of transport had been created. Legislative existing measures to reduce the number of the accidents could be thereby founded associated with the legislation, while other preventive measures in addition to the legislation for the accidents were considered as well to prevent the accidents. Especially for the drivers and other primary stakeholders who were involved in the entire process of the transportation, more concentrated effort was needed to improve the safety awareness of the personnel.

Key words: Chemical dangerous goods transport, accidents, risk, preventive measures, legislation, safety awareness.

Preface

The purpose of this report is to reach the requirements of the last semester of the MSc Risk and Safety Management program from Aalborg University, meaning that this report will be a master's thesis that contains 30 ECTS. This thesis will be mostly qualitative study aiming at how to prevent chemical dangerous goods transport accidents by road in China.

The motivation of discussing this topic is stimulated by a latest case study of Wenling Accident in China, which caused 19 deaths and 172 injuries due to more than one explosion, leading to quite severe consequences. Therefore, the thesis will mainly investigate the various causes of the accidents, discovering legislative existing preventive measures and other additional potential preventive measures that can be done to reduce the number of the accidents.

I would like to express my millions of thanks to my supervisors Hanna Barbara Rasmussen from University of Southern Denmark, and José Guadalupe Rangel Ramirez from Aalborg University, for the big support and useful suggestions towards the questions that I had. They are warmhearted to give me the guidance of the thesis all the time. Thank you, my dear supervisors.

Acronyms	**Explanation**
CCSA	China Chemical Safety Association
CDC	Centers for Disease Control and Prevention
ESC	Electronic Stability Controller
GPS	Global Position System
LPG	Liquefied petroleum gas
TPMS	Tire pressure monitoring system
WHO	World Health Organization

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1. Introduction

According to Centers for Disease Control and Prevention (CDC), road traffic injuries have become a global problem, which cannot be underestimated any longer. Relevant statistics have stated that the number of road traffic deaths reaches 1,35 million every year all over the world, and daily mortality of road traffic is around 3,700 (Centers for Disease Control and Prevention). In order to reduce these numbers, road traffic efforts are still needed by a long way.

Besides the high mortality of road traffic crashes, according to a report from WHO, from 20 to 50 million people are injured every year, and among them the vulnerable group like pedestrians, cyclists and other road users occupies more than a half. Especially for children and young adults between 5 and 29 years old, road traffic injuries are the main cause of their deaths. Another group involved in road traffic is young males under 25 years, which is proved by 73% of road traffic deaths in that age group. Moreover, the report indicates that the risk of road traffic deaths is higher in most of low- and middle-income countries, since 93% of road traffic deaths are observed in these countries (World Health Organization, 2018). This can be approved in the Figure 1:

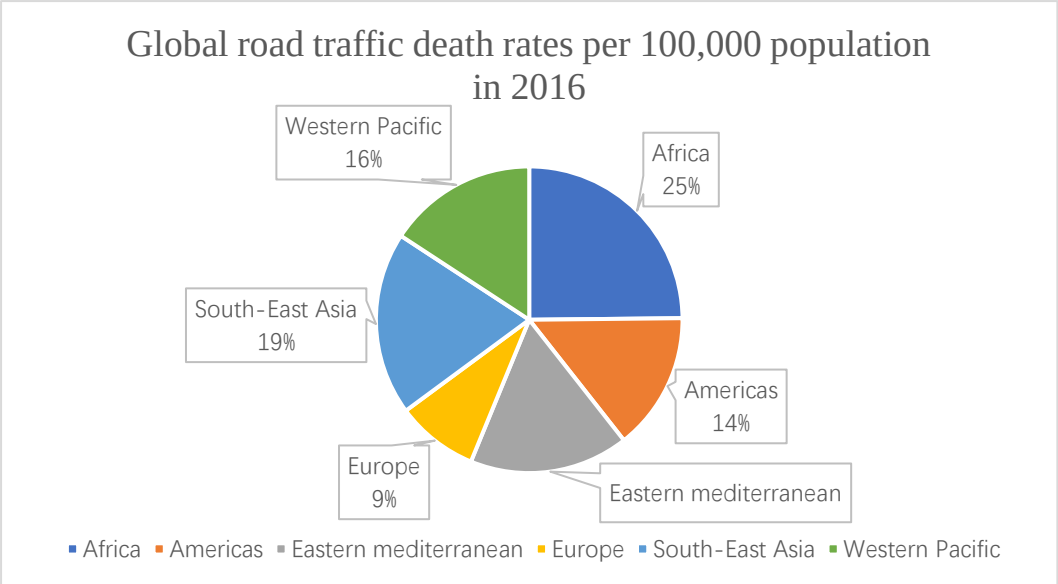

Figure 1. Global road traffic death rates per 100,000 population in 2016

Source: (World Health Organization, 2018).

As can be seen in the Figure 1, in different regions in the world, Africa occupies the highest road traffic death rate, with a proportion of 25% compared to others. Also, the second highest one is in South-East Asia, containing 19%. Therefore, there is not a significant difference between the first two regions. However, it should be noticed that Europe has merely 9% of road traffic death rate, which is quite far away from the others. And most of low- and middle-income countries belong to Africa and South-East Asia, which is the reason behind their high death rates.

In addition, the consequences of road traffic deaths are generally unacceptable, since either an injury or a death will increase the economic pressure of a family for better or worse, reflected in abundance of treatments and disability in the worst case. Moreover, some huge road traffic accidents will affect national economies, by destroying roads and other infrastructure. Some special accidents will have a negative impact on the environment as well.

As a result, it is of great importance to take road traffic into consideration and hereby improve the road safety.

1.1. Occupational safety and health of drivers

The number of road traffic deaths cannot be disregarded anymore, since it has experienced a growing stage nowadays (World Health Organization, 2018). In other words, the risk in relation to driving in different aspects is becoming higher, therefore occupational safety and health of drivers is supposed to be considered in a way.

In the road traffic sector, due to the increase of the risk towards accidents of chemical dangerous goods transportation, occupational safety and health of drivers should be taken into consideration, especially for road safety and the sector of dangerous goods transport. Although the proportion of physical work factors exposed to chemical substances is not high, compared to other exposures, it is still needed to be considered, because the chemical substances will cause harm to both environment and human (Statistical analysis and preventive measures of hazardous chemicals transport accidents from 2013 to 2017, 2019). The subsequent consequences of chemical substances cannot be predicted, and they are likely to result in explosions. Thus chemical dangerous goods transport will be focused on the road traffic.

When operating vehicles, lots of factors will affect driver's condition, including different kinds of aspects, and there are many risks that are likely to occur during the chemical dangerous goods transport.

For instance, accident risks are one of the mostly common risks in the sector of chemical dangerous goods transport. Fire and explosions are quite easy to be triggered, because of active chemical reactions. Obviously, exposures to dangerous substances need to be considered as well while loading and unloading, since they are hazardous and can cause severe consequences to human, environment and even society.

Climatic risk is inevitable for the driver in certain conditions, because bad weather conditions are external and hard to change. The driver needs to adapt to the changing weather and react against it as soon as possible. There is another a possibility of risk of falls from vehicles and other transport means, which should be noticed as well (European Agency for Safety and Health at Work, 2011).

Moreover, organizational factors play a role in it as well, because skills and training for drivers are vital when transporting. Generally speaking, experienced drivers will be appointed preferentially since they possess more knowledge than new hands.

It should be also noticed that working time is one of the factors as well. The reason behind it is that the length and the shift of work will affect the driver's condition for better or worse. Particularly long-time transport during the night for the driver is a challenge and fatigue is quite easy to arise (European Agency for Safety and Health at Work, 2011).

1.2. Case study: Wenling Accident

When considering occupational safety and health in road traffic, a major accident in China was observed, due to the two explosions and its unacceptable consequences. Therefore, the thesis is inspired by this accident of tanker truck explosion in Zhejiang Province, China. The accident captured much attention and caused hot discussions in the society, because this accident has been regarded as one of the most dangerous explosion accidents of liquefied petroleum gas[1] (LPG) tanker truck during recent 20 years. The reason behind it is that this accident has caused destructive consequences, ending up with 19 deaths, 172 injuries (24 severely injured) and damaged surroundings (Science and Technology Daily, 2020).

This accident took place on the Wenling exit of the Shenhai Expressway, where an LPG tanker truck exploded at first. Later on, the fragments of the tanker truck flew into and hit against the factory and the village nearby. A second explosion had been triggered and plumes of smoke had covered the overall area, because of the chemical reaction of leaked liquified gas and air. Hundreds of buildings in the village had been destroyed and collapsed. Meanwhile acrid fumes of burning had spread and thousands of debris were scattered on the roads.

[1] Liquefied petroleum gas: A type of gas that is the mixture of flammable hydrocarbon gases and can be used as fuel (Hahn, 2020).

It is founded that the truck was not collided with other vehicles, which excluded rear-end collision. The direct cause of this accident was investigated, according to the report from Zhejiang Provincial Department of Emergency Management. It is because the driver failed to slow down the speed while driving to the curved road where the speed was limited to 30 kilometers per hour. Afterwards, the front head of the tank body hit violently the guard rails, leading to the rapid leakage of the liquified petroleum gas and finally explosions. It is said that the overall energy of an exploded normal LPG tanker truck causing the explosions was equal to a small atomic bomb, which could result in extremely severe consequences (Zhejiang Provincial Department of Emergency Management, 2020).

There is another organizational cause for this serious accident, which is related to the company which owns the truck. The report also has shown that the GPS dynamic monitoring was not executed in the company, which resulted in the illegal behavior of the driver (Zhejiang Provincial Department of Emergency Management, 2020). Moreover, from 2016 to 2018, the company was penalized by local road transport authorities 10 times, fined 14,100 Yuan (13,147 DKK) in total. Four times of the punishments were due to the failure of carrying out comprehensive vehicle performance testing and technical grade assessment. Besides, one thing should be noticed is that the company was involved four times in legal issues, concerning traffic accident liability, between 2014 and 2019. Thus the reputation of the company was no doubt affected and the company was not convincing towards the public at all (Antpedia, 2020).

Moreover, people tend to be exposed to a great number of risks in chemical dangerous goods transport due to the severe consequences of the accidents. As a result, the aim of the thesis will focus on road transport regarding chemical dangerous goods in China, which is the motivation of this thesis.

1.3. Problem statement

As inspired by the Wenling Accident in China, the focus point of this thesis is aimed at chemical dangerous goods transport. During these years more and more road accidents concerning dangerous goods transport have been witnessed, which has also caused some repercussions in the society. As a consequence, in order to reduce the risk of the chemical dangerous goods transport, the problem statement of this thesis will be:

"How can the investigation of the causes and preventive measures reduce the risk of chemical dangerous goods transport by road in China and prevent relevant accidents?"

To answer this main problem, three sub-questions are divided as following:

1) *What are the main causes for the chemical dangerous goods transport accidents?*
2) *What kind of legislative existing mitigation measures are implemented?*
3) *What other preventive measures in addition to the legislation can be done to prevent the accidents from happening?*

In order to accomplish the problem statement, there are some useful theories and methods that will be introduced in the following Chapter 4 - Methodology. Moreover, a risk assessment will be conducted to investigate the causes of the accidents, by applying the bow-tie analysis, root cause analysis and risk matrix. A stakeholder analysis including a stakeholder mapping, the theory of planned behavior, and the Haddon Matrix analysis will be adopted as well to identify possible preventive measures. In this way, by answering sub-questions step by step, the general structure of the thesis comes out, which is to say, this thesis will tend to qualitative analysis.

2. Establishing the context

In recent years the development of the petrochemical industry in China has experienced an increasing stage. As a consequence, the total amount of production, usage, storage, transportation, import and export regarding hazardous chemical dangerous goods has been increased, along with the variety of hazardous chemical dangerous goods, such as natural gas, liquefied petroleum gas etc. (Hu, 2021). The rapid development in the industry hereby leads to the large demand of chemical dangerous goods transport in the industry. Relevant statistics have shown that in 2017 the total volume of chemical dangerous goods transportation in the entire industry had exceeded 1.6 billion tons, which had achieved more than an average percentage of 10% in annual growth. Moreover, road transport for chemical dangerous goods has become the mainstream in China, containing 60% of the total transport volume (Logistics Salon, 2018).

Category	Description
Category 1: Explosives	Articles that can generate a large amount of gas and heat instantly under the external forces, due to violent chemical reactions, which will cause explosions.
Category 2: Compressed gases and liquifies gases	1) Flammable gases 2) Non-combustible gases (including combustion-supporting gases) 3) Toxic gases
Category 3: Flammable liquids	Easily volatile at room temperature and its vapors mixed with air will become an explosive mixture.
Category 4: Flammable solids substances spontaneous combustion substances and substances emitting flammable gases when wet	Flammable solids refer to solids that have low ignition points and are easily ignited by external forces. Spontaneous combustion substances

	refer to substances that can easily burn themselves in the air. Substances emitting flammable gases when wet refer to substances that react violently when exposed to water or moisture and emit a large amount of flammable gas and heat.
Category 5: Oxidizing substances and organic peroxides	Oxidizing substances refer to substances that have strong oxidizing properties and can easily generate oxygen and heat. They are also sensitive to heat, vibration and friction. Organic peroxides refer to organic substances that are flammable and explosive, easily decomposed, and extremely sensitive to heat, vibration and friction.
Category 6: Poisons and infectious substances	Substances that can have biochemical interactions or biophysical changes with body fluids and tissues, thereby disrupt or destroy the normal physiological functions of the body.
Category 7: Radioactive substances	Substances that are radioactive and can produce dangerous radiation.
Category 8: Corrosives	Solids or liquids that can ignite human tissues and cause damage to metal and other objects.

Table 1. Classification of commonly used hazardous chemicals

Source: (Chinese Center for Disease Control and Prevention, 2015)

Table 1 shows the classification and descriptions of different hazardous chemicals. In this way, one can argue that hazardous chemicals are quite harmful due to their own properties, which will influence the safety and stability of transportation, meaning that accidents are quite easy to arise.

According to statistics from China Chemical Safety Association (CCSA), between the year of 2013 and 2017, 356 chemical dangerous goods transport accidents were recorded and the number of accidents were climbing up year by year. Among these 356 accidents, the largest number was in 2016 with 104 accidents, while the smallest number was in 2013 with merely 33 accidents. Another interesting point is that the deaths were not as high as perceived, because merely 15 deaths per year were shown in the statistics. The reason behind it is that these accidents were mostly attributed to the leakage of hazardous chemicals, so that the number of deaths of personnel was not that high, meaning that the injuries were far more than the deaths (Statistical analysis and preventive measures of hazardous chemicals transport accidents from 2013 to 2017, 2019).

3. Theoretical approach

After a general background information was defined, this chapter will mainly describe relevant theories and analysis that will be applied in the thesis, as well as their purposes and the reasons why they are chosen to be used.

As the main research question is divided into three sub-questions, there are different approaches to answer the three questions respectively. For the first sub-question, a risk assessment will be conducted based on ISO 31000 standard, consisting of three steps. This risk assessment will demonstrate the overall process of identifying risks, analyzing identified risks and evaluating those risks, in order to reduce the risks and in a way to prevent them from happening.

Figure 2. Risk assessment process

Source: (ISO 31000:2018)

According to Figure 2, in order to conduct a risk assessment, there are three main steps that need to be followed. To be more specific, risk identification is the first step in the risk assessment process. The purpose of it is to identify relevant risks concerning chemical dangerous goods transport. Here a bow-tie analysis will be introduced, which is one of the risk management tools, in order to have a general risk picture of chemical dangerous goods transport. In the bow-tie diagram, various causes, preventive measures, mitigation measures and consequences of the event will be identified, which is quite simple and easy to understand (Aven, 2015). For risk analysis, after identifying the risks, a root-cause analysis will be applied in this step, by defining the root causes of problems or events through what, how and why they happened, in order to reduce their reoccurrences. This analysis can also be typically used for accident investigation, which is pointing to chemical dangerous goods transport accidents in the thesis (Washington State Department of Enterprise Services). Risk evaluation is the last step in the risk assessment step, in order to achieve that, the risk matrix will be used based on the criteria of different levels of likelihood and impact. The purpose of it is to compare the different risk levels of the identified risks and hereby prioritize them, to determine the significance of the risks.

For the second sub-question, none of relevant theories and approach will be used, since it will be mainly related to the legislation and regulations.

To answer the third sub-question, a stakeholder analysis will be performed, by introducing different relevant stakeholders involved in chemical dangerous goods transport. Moreover, a stakeholder mapping will be created to distribute these identified stakeholders based on the power and interest criteria (Olander, 2007). In this way, stakeholders with higher power and interest should be taken into consideration, which will also contribute to the decision-making process of reducing the risk of chemical dangerous goods transport.

Moreover, the theory of planned behavior will be applied, in order to discover the relationships and influences between attitudes and behaviors. This theory will be related to some parts in psychology, as it describes beliefs, attitudes, behavioral intentions and behaviors, which can predict actual behaviors ultimately (Ajzen, 1991).

Last but not least, Haddon Matrix analysis is another proper tool to use, in order to find out possible injury prevention strategies, which will be analyzed from three aspects in the time of the event: pre-event, during the event and post-event (Runyan, 1999).

4. Methodology

This chapter will describe the research philosophy and research methods, that will be used to answer the main research question. To be more specific, the way of how to answer the research question, what kind of data were collected, and how they were collected are the important contents for this methodology chapter.

With regard to research philosophy, this term is defined as research beliefs and assumptions towards knowledge. In other words, it represents what should be studied, what should not be included and how it should be investigated, based on the research questions, in a particular field to develop knowledge.

In order to figure out the research philosophy, three types of research assumptions are supposed to be considered. First of all, ontology refers to examining the nature of knowledge, which determines the way in which the research questions are investigated.

Moreover, epistemology is related to how the knowledge comes into being, generally pointing to assumptions that can be considered as acceptable and valid knowledge in a discipline. In addition, axiology concerns the values of researchers when conducting the research, since the role of values during the research process can influence the reliability of research results. In brief, these three elements are important guidance to distinguish the research philosophy.

After defining the research philosophy, interpretivism has been chosen for the research questions in this thesis. It underlines that human create meanings, different from natural science, and these meanings are the things that should be studied. The purpose of interpretivism is to develop comprehensive and overall understandings towards social contexts. In this thesis, in order to answer research questions, relevant theories and methods will be applied to conduct corresponding analysis. For instance, a risk assessment will be carried out for the first sub-question. And in this risk assessment, lots of interpretations and perceptions will be mainly focused on to complete the analysis. Thus this thesis will tend to being subjective rather than objective.

In terms of research methods, they refer to data collection techniques in this chapter. Since the research philosophy is chosen as interpretivism, a qualitative study will be adopted to answer research questions. A case study and an interview conducted by others are considered in this thesis to formulate the research design. Therefore the information from these findings will be mainly secondary data.

Here the case study refers to the latest transport accident in China, as mentioned in Chapter 1.2. Case study: Wenling Accident, this report illustrated the detailed information of the entire process of how the accident would take place, including the causes of it, the personnel and companies involved in the accident, and lessons learned (Zhejiang Provincial Department of Emergency Management, 2020). As for the interview, a report based on the interview towards a driver working on chemical dangerous goods transport for more than 10 years was used, which stated the driver's personal views towards the occupation and current situation of the industry, as well as normal working condition (Gao, 2020).

When it turns to the quality of methodology, there are two dimensions that are made of reliability and validity from scientific canons. Reliability concerns consistency and replication of the research results from the research project. While validity refers to accuracy of analysis that will be applied in the thesis.

As far as it is concerned, reliability seems more difficult to reach. It cannot be assured that the thesis is replicated or repeated by other researchers, so that the results are hard to be considered consistently. However, if another similar research project does exist, and there is no big difference between its findings and the results of the thesis, then the thesis can be considered reliable in a way.

In terms of validity, the interview can be generally regarded valid in a way, when embarking carefully on questions that will be used in the interview. Clarifying questions and their understandable meanings can help establish trust and support between interviewers and interviewees, providing the opportunity for the interviewers to ask interviewees to check the results of the interview (Saunders, M., Lewis, P. & Thornhill, A., 2009). However, the data collection method from the interview in the thesis was not clearly stated in the report, thereby the validity of data cannot be ensured.

Moreover, another limitation in the thesis can be the bias of individual values from researchers and research participants, which will normally exist when dealing with research questions. Therefore the way of how researchers treat their own values towards research questions, and how to treat the values of research participants, should be taken into consideration.

5. Risk Assessment

In order to answer the first sub-question in accordance with theoretical approaches and methodology, a risk assessment will be performed in this chapter, consisting of risk identification, risk analysis and risk evaluation.

When it comes to the first step of this risk assessment, risk identification, a bow-tie analysis will be illustrated to give an overall risk picture of a chemical dangerous goods

transport accident. In this way, different possible risks towards a chemical dangerous goods transport accident will be identified, along with their causes, preventive barriers, mitigation barriers and consequences.

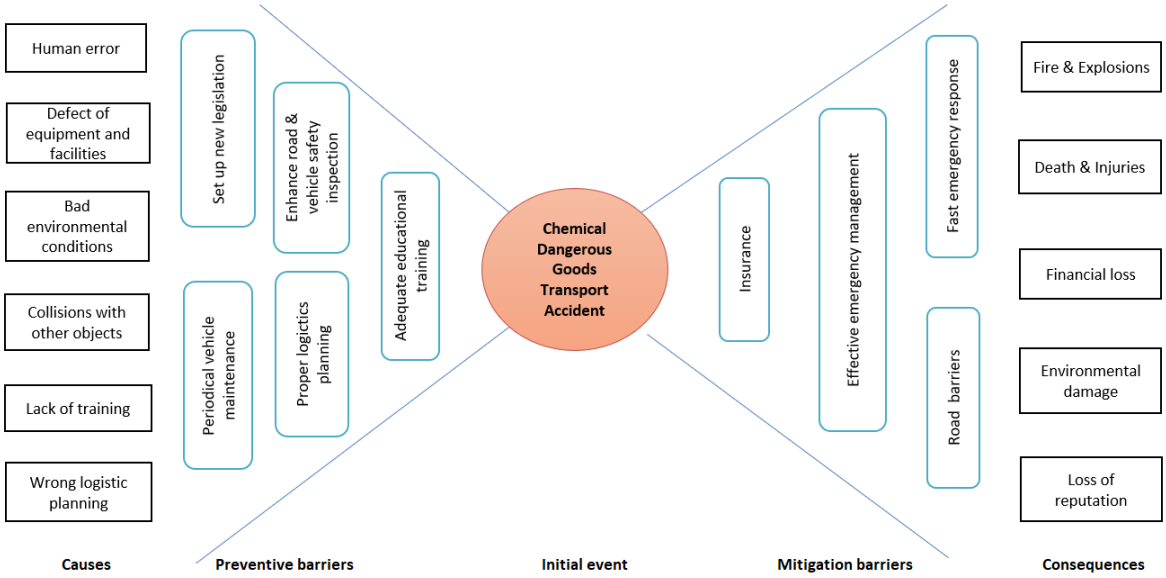

Figure 3. A bow-tie analysis of a chemical dangerous goods transport accident

Source: Author

As can be seen from Figure 3, the initial event of this bow-tie analysis is a chemical dangerous goods transport accident without doubt, as it is the main topic of the thesis. First of all, five different aspects can be included to give a view of what kind of risks are potential causes of an accident. In this side, human error is a common risk that is involved in various accidents, because human factor referring to drivers is inevitable when it comes to accidents. Fatigue, overspeed, alcohol drinking and other influences caused by human are sometimes hard to avoid when driving an oversize vehicle, especially during the nights or under a circumstance of long-time driving.

Equipment and facilities are also one of the elements that will have an impact on accidents, since ineligible hazardous chemical transport equipment such as unsealed gas tanker, can result in unexpected consequences while transporting. Thus the defect of these relevant equipment and safety protection facilities on vehicles should be taken into consideration. On the other hand, equipment defect can be related to vehicle error, which refers to damaged tail lights, brake failure and other vehicle issues.

Uncertain environmental issues including weather conditions and road conditions, can also have an influence on the causes of accidents. Weather conditions can be predicted by investigating weather forecasts, however, changeable weather conditions, normally varying to strong storms cannot be avoided in some specific regions, due to geographic locations. Similarly, in some regions the road conditions are not as well-structured as others, which makes it easier to trigger accidents.

Collisions with other objects while transporting should be taken into consideration, and the way of collisions can be differentiated: one is a collision between two vehicles; the other one is a collision of the turnover by vehicle itself or collided with guard rails. An interesting point in this aspect is that it can be related to human error, since collisions are generally attributed to human factor, which is to say, mistakes from drivers. Moreover, they can also be attributed to vehicle error, since malfunction of components on vehicles is likely to arise.

In addition, another important issue to be considered is organizational management, due to its influence on consequences of an accident. Weak organizational management reflects in lack of training regarding drivers and wrong logistic planning of routes, which will generate accidents in a way. Especially for drivers, common training programs are needed for them, and knowledge concerning safety protection of chemical dangerous goods is worth to being taught as well. In terms of logistic routes, adopting different routes will influence road conditions and driving time, which is supposed to be taken into consideration.

As for preventive barriers referring to the second element of the Figure 3, these barriers are the ones that can be carried out before an accident happens, in order to prevent an accident from happening. Adequate education training programs in relation to driving and safety protection of chemical dangerous goods are supposed to be launched in the organizations, here referring to transport companies. In this way, human error and mistakes can be reduced in a large extent, by absorbing comprehensive professional knowledge of driving and chemical dangerous goods. Setting up new legislation will help to prevent accidents as well, by prohibiting night driving for instance. The reason

behind that is the enforcement of new legislation is compulsory towards the society. In other words, transport companies and drivers in these companies are supposed to comply with legislation and cannot violate regulations. In this way, road and vehicle safety inspection will also be enhanced to some extent. To be more specific, road conditions will be improved in a way, as well as road infrastructure. The decision making of logistic routes can be also promoted by choosing a proper one. Moreover, periodical vehicle maintenance will ensure normal operation of safety protection equipment and facilities under safety inspection.

With regards to consequences, fire and explosions are likely to take place if the chemical reactions are stimulated, which will cause serious environmental damage without doubt and nearby surroundings can also be destroyed by the debris from the fire and explosions. Especially for the environment, the remediation is kind of challenging for the society, because it will take long time and require lots of resources to deal with chemical pollution. In this way, financial loss is unavoidable both for the government and families. Government is responsible for recovering affected roads and constructions, while for families the reason is death and injuries caused by the accident, not mention if there are irreversible impairment on drivers, pedestrians or other people involved in the accident. Moreover, from an organizational point of view, frequent accidents will affect the reputation of the transport companies without doubt and the operation of the transport companies will hereby become difficult.

Last but not least. when it comes to mitigation barriers referring to the fourth element of the Figure 3, these barriers are ones that can be done after an accident happens, in order to mitigate the consequences of the accident. Fast emergency response is apparently demanded after an accident happens, in order to save more people and resources. As a result, effective emergency management is supposed to be carried out, from both national and regional level. Furthermore, road barriers should be placed around the accident location on the road, in order to give other people such as drivers, pedestrians and motorcyclists caution, towards the accident and prevent consecutive accidents. As for reducing financial loss, insurance can be a proper choice to alleviate

economic burden of families.

All in all, this bow-tie analysis illustrates a general risk understanding of a chemical dangerous goods transport accident, which can be briefly summarized from four aspects: organization, human, vehicle and environment. In this way, in order to conduct a risk analysis from these four aspects, a root cause analysis will be introduced in the following context, which will mainly analyze potential risks for accidents and investigate the fundamental causes of a chemical dangerous goods transport accident.

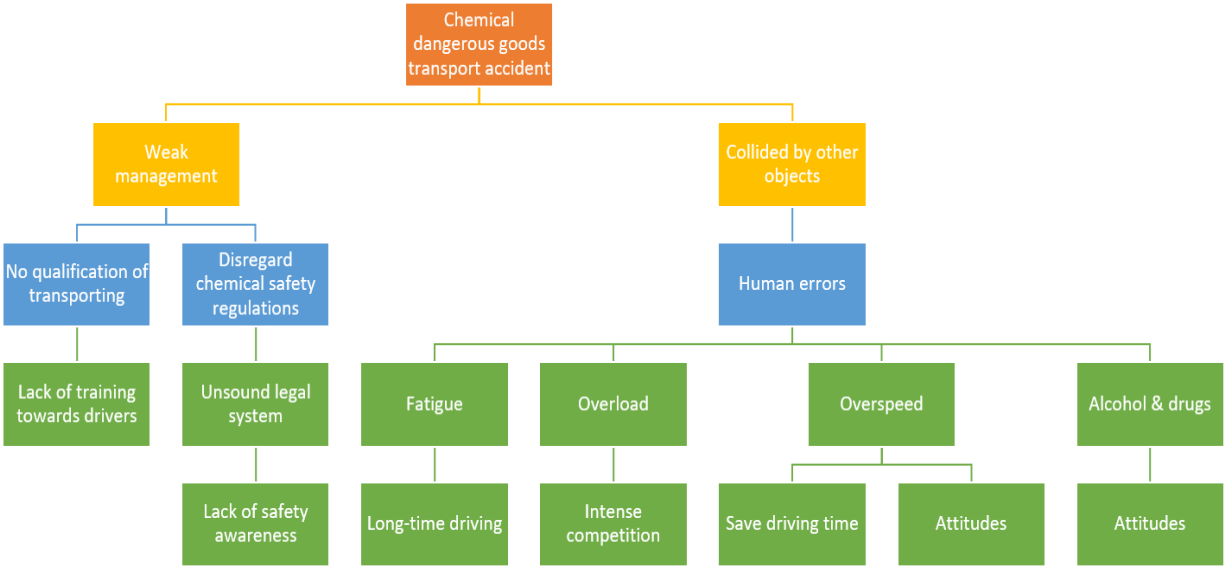

Figure 4. Root cause analysis diagram (organization and human)

Source: Author

According to Figure 4, this diagram illustrates the organization and human part of root cause analysis, along with the main problem of the chemical dangerous goods transport accident. The first reasons for the accident are consisting of two factors, weak management and collisions with other objects. As for weak organizational management, it can be attributed to two aspects: transport companies and government. For transport companies, the reason for the weak management reflects in no qualification of transporting and ends up with lack of training towards drivers. Moreover, intensive competition in the industry can be another reason for it, since a lot of small companies lower the prices of transport. For earning more benefit, the labor force in these companies is normally low cost, meaning that the drivers are likely to be less educated,

which can also be supported by the interview mentioned in Chapter 4. Methodology (Gao, 2020). For the government, disregarding chemical safety regulations causes its weak management, and this disregard reflects in unsound legal system, which is ultimately due to lack of safety awareness.

In terms of collision with other objects, here human errors are the main factor that will result in collisions, either collided with other vehicles or guard rails. The reasons for human errors are divided into four aspects: fatigue, overload, overspeed and alcohol and drugs. Fatigue is mostly caused by long-time driving and this circumstance is likely to arise during the driving time (Gao, 2020). Overload is another common issue for accidents due to intense competition among transport companies. Overspeed can be attributed to the perception of saving driving time or attitudes of drivers, since some drivers are used to overspeed. Alcohol and drugs can be also regarded as an issue on attitudes of drivers for the accidents, as it can be a habit for some drivers before driving (Statistical analysis and preventive measures of hazardous chemicals transport accidents from 2013 to 2017, 2019).

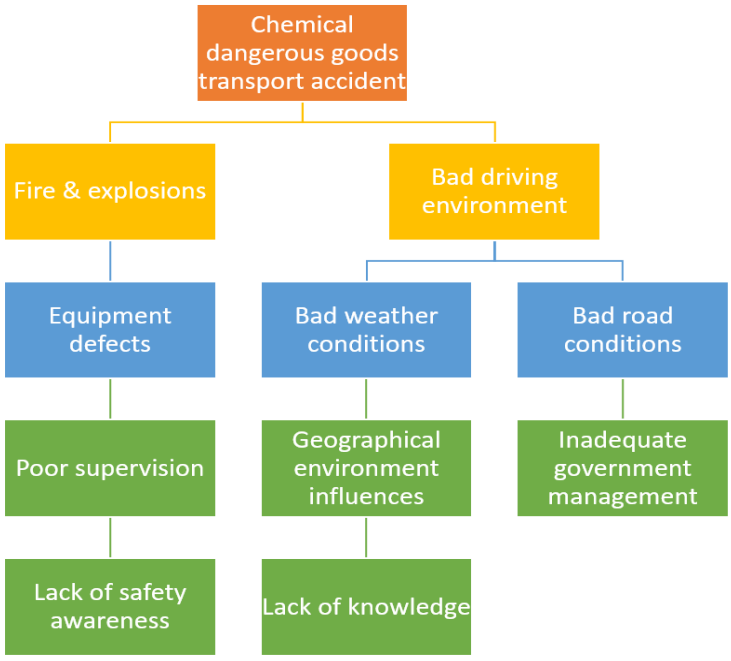

Figure 5. Root cause analysis diagram (vehicle and environment)

Source: Author

As can be seen from Figure 5, this figure demonstrates vehicle and environment part for the chemical dangerous goods transport accident. The symptom of the accident can be divided into two factors: fire and explosions on vehicles, and bad driving environment. For the vehicle part, fire and explosions can be caused by equipment defects, for instance, unqualified gas tanker, which can be due to poor supervision of transport companies or government and this can be ultimately attributed to lack of safety awareness as well.

In terms of bad driving environment, it consists of bad weather conditions and bad road conditions. For bad weather conditions, the reason for it can be geographical environment influences, since the weather in some regions is changeable and unpredictable in some cases. Drivers are mostly unaware of the bad weather conditions when driving on specific routes in these regions, which is due to lack of knowledge. For bad road conditions, it is mainly attributed to inadequate government management, which can also be related to weak organizational management.

In summary, this root cause analysis clearly describes the problem referring to the chemical dangerous goods transport accident, and illustrates sequent reasons of the accident step by step from organization, human, vehicle and environment aspects. In this case, the main causes for the accident can also be generalized from these four aspects, as mentioned in the diagram. Moreover, the root causes for the accident can be summarized as lack of safety awareness, lack of safety knowledge and attitudes.

As long as the root cause analysis is completed, the causes are needed to be evaluated from different level of impact and likelihood of the chemical dangerous goods transport accident, in order to see whether they can be accepted (PivotPoint Security, 2016). As the identified root causes are kind of difficult to classify into different risk levels, and more detailed information regarding their likelihood is hard to investigate, four aspects of the risk towards chemical dangerous goods transport accidents are hereby to be evaluated in the risk matrix.

In the risk matrix, impact and likelihood are regarded as two criteria of the matrix, in order to classify different levels of the risk. For both impact and likelihood, three

categories are defined: low, medium and high. In terms of the overall risk level in the risk matrix, three colors represent three different risk levels: green (low risk that can be tolerated), yellow (medium risk that can be mitigated) and red (high risk that cannot be acceptable).

Since there are three main categories in likelihood and impact, it can be assumed that the percentages of attributes of likelihood and impact can be divided into three categories as well: less than 30%, 30% to 60%, and more than 60%. The following context defines different attributes for likelihood and impact:

Low likelihood: percentage of number of accidents less than 30%

Medium likelihood: percentage of number of accidents from 30% to 60%

High likelihood: percentage of number of accidents more than 60%

Low impact: percentage of injuries and deaths less than 30%

Medium impact: percentage of injuries and deaths from 30% to 60%

High impact: percentage of injuries and deaths more than 60%

	Vehicle	Human	Road	Other factors
Number of accidents	4.12%	92.76%	0.12%	3%
Deaths	5.93%	88.29%	0.16%	5.62%
Injuries	5.22%	90.66%	0.21%	3.91%

Table 2. Percentages of different influence factors in number of road traffic accidents, deaths and injuries in 1998, China

Source: (Pei & Wang, 2004)

Since the data of influence factors regarding chemical dangerous goods transport accidents is extremely difficult to investigate, it can be assumed to be similar to the data from road traffic accidents, even though with small differences. Table 2 illustrates percentages of vehicle, human, road and other factors in number of road traffic accidents, deaths and injuries, which can be used as the basis for the risk matrix.

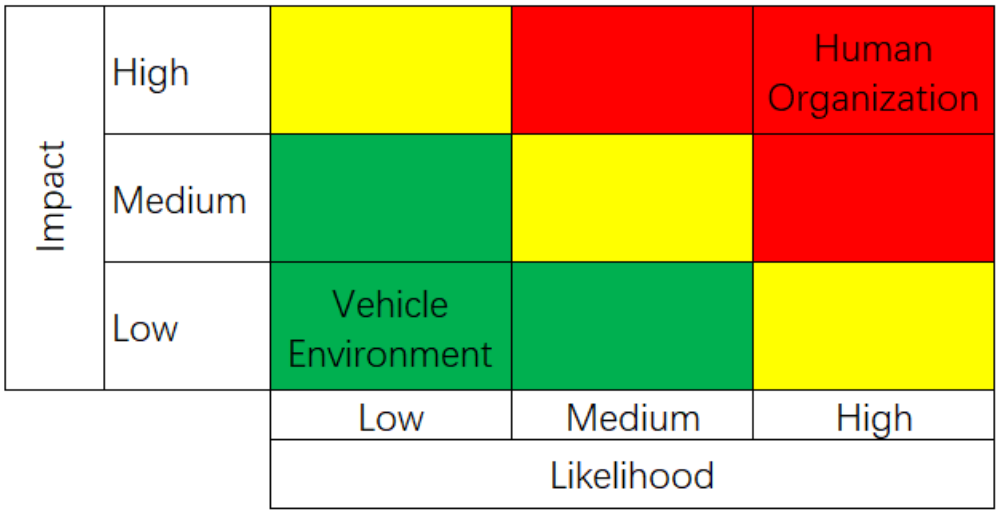

Figure 6. Risk matrix of the four aspects

Source: (Pei & Wang, 2004).

According to Figure 6, four aspects are clearly classified in the risk matrix with different levels of the risk, with two high risks and two low risks. Human and organization are considered as high risks, because the percentages of human in number of road traffic accidents, deaths and injuries are all around 90%, which can be seen as high impact and high likelihood. The reason that organization is at the same level as human, is that organizational management activities involve participation of humans. In other words, organization can be regarded as a part of human in a way, since the aspect of human is broader.

Moreover, vehicle and environment (referring to road) can be placed in the low-risk category, as their percentages are far less than human. As a result, human and organization aspects are supposed to be prioritized and relevant risks in these two aspects are supposed to be mitigated to a lower risk level. Even though vehicle and environment are considered as low risks, these two aspects should still be taken into consideration.

5.1. Risk assessment summary

This chapter combines risk identification, risk analysis and risk evaluation with different approaches, in order to answer the first sub-question. The first bow-tie analysis shows a general risk picture of chemical dangerous goods transport accidents, and it can be summarized that the risk of chemical dangerous goods transport accidents can be defined as four aspect: organization, human, vehicle and environment. Organization represents not only transport companies, but also government in both national and regional levels. Organizational management in transport companies more reflects in drivers and vehicles, while management in government is more related to legislation and regulations. Human aspect here refers to human error, which points to different influence factors resulting in accidents caused by human and can also be related to their daily habits and attitudes, such as overspeed and alcohol drinking. Vehicle is more considered as equipment and facilities that are installed on vehicles, including equipment of vehicles and safety protection facilities. Environment is divided into weather conditions and road conditions: weather conditions are hard to predict in some specific regions, while road conditions can be improved under the intervention of the government.

After defining these four aspects of the risk, a root cause analysis is performed to figure out the direct and fundamental causes of the accidents from each aspect. Sequent reasons are demonstrated step by step, and ultimately the fundamental causes are concluded as: lack of safety awareness, lack of safety knowledge and attitudes of drivers, which can be the indirect causes of the accidents and usually cannot be digged into further aspects. While the direct causes are the ones that result in the accidents directly, for instance, overspeed as investigated in the case study of Wenling Accident (Zhejiang Provincial Department of Emergency Management, 2020).

Since the root causes are hard to be quantitated and the data of influence factors in chemical dangerous goods transport accidents is also difficult to gather, similar information in road traffic accidents is thereby used for reference to conduct risk evaluation, which can be also one of the limitations in the thesis. As a consequence,

human and organization are regarded as high risks, whilst vehicle and environment are considered as low risks. It can be concluded that human and organization aspects should be prioritized, which can lead the direction of preventive measures to reduce the occurrence of the accidents.

6. Legislative existing measures

This chapter will describe relevant legislation and regulations regarding chemical dangerous goods transport, which mainly points to Regulations Concerning Road Transportation of Dangerous Goods, also known by JT/T 617. This legislation was published by Ministry of Transport of the People's Republic of China (abbreviated as Ministry of Transport) in 2018, which was executed from the 1st of December, 2018 officially. Inspired by United Nations Recommendations on the Transport of Dangerous Goods and The European Agreement concerning the International Carriage of Dangerous Goods by Road, JT/T 617 Regulations has improved the legal system of dangerous goods transportation management, based on these international dangerous goods transport regulations.

Moreover, this JT/T 617 has become safety management standard in the industry of dangerous goods transport by road, which consists of seven parts, including General Provisions (JT/T 617.1), Classification (JT/T 617.2), Index of Dangerous Goods Name and Transportation Requirement (JT/T 617.3), Provisions for the Use of Transport Packaging (JT/T 617.4), Consignment (JT/T 617.5), Provisions concerning the Conditions of Carriage, Loading, Unloading and Handling (JT/T 617.6), and Transport Conditions and Operational Requirements (JT/T 617.7). This regulation also introduces a series of standards and provisions from different aspects that are likely to be involved during the overall process of dangerous goods transport (REACH24H, 2018).

In addition to JT/T 617, the Chinese Ministry of Transport has established other relevant regulations in recent years, which are associated with JT/T 617 standards and can be regarded as supplements of JT/T 617. Here is referring to Measures for the Administration of Road Transportation Safety of Hazardous Goods published in 2019 and Safety Technical Specifications for Commercial Vehicles for Road Transport of Dangerous Goods set up in 2020, which can be considered as existing preventive measures towards chemical dangerous goods transport (Ministry of Transport of the People's Republic of China, 2020).

6.1. Measures for the Administration of Road Transportation Safety of Hazardous Goods

First of all, Measures for the Administration of Road Transportation Safety of Hazardous Goods defines current responsibilities and requirements of relevant organizations involved in the entire process of road dangerous goods transport. This regulation also sets up the standards for the technical conditions of each transport link, with the supervision of various regulatory departments. It can also be a guidance of the implementation of principles concerning safety first and thereby facilitate the safety of transportation in a way.

"The shipper shall check the following items before filling or loading the cargo; if it does not meet the requirements, it shall not be filled or loaded:

(1) Whether the vehicle has a valid driving permit and operating permit;
(2) Whether the driver and escort personnel have valid qualification certificates;
(3) Whether the transportation vehicles, tank bodies, movable tanks, and tank boxes are within the valid period of inspection;
(4) Whether the dangerous goods filled or loaded are consistent with the items specified in the dangerous goods waybill;
(5) Whether the dangerous goods filled are within the range of the suitable medium list

of the tank body of the tank vehicle, or meet the requirements of the guidelines for the movable tank and the applicable code of the tank." (The Government of the People's Republic of China , 2019)*, chapter 5*, § 28.

"The carrier of dangerous goods shall carry dangerous goods in accordance with the approved load quality of the transport vehicle, and shall not overload." (The Government of the People's Republic of China , 2019)*, chapter 4*, § 23.

These regulations define clearly responsibilities and requirements for the shipper before filling or loading the cargo, helping to set up loading inspection system and ensure that the vehicle, driver and other relevant personnel hold the valid permit and qualifications of transportation. In this way, the safety management of filling or loading can be strengthened in some degree, and vehicle error regarding the tank can be reduced as well.

"Dangerous goods transportation vehicles must not exceed 80 kilometers per hour on expressways, and must not exceed 60 kilometers per hour on other roads. If the speed indicated by the road speed limit signs and markings is lower than the above-mentioned prescribed speed, the speed of the vehicle shall not be higher than the speed indicated by the speed limit signs or markings." (The Government of the People's Republic of China , 2019)*, chapter 7*, § 46.

"Except as otherwise provided by laws and administrative regulations, if the public security organs comprehensively consider relevant factors and need to take measures to restrict the traffic of dangerous chemicals through expressways in accordance with the law, the restricted traffic period should be determined between 0 o'clock and 6 o'clock." (The Government of the People's Republic of China , 2019)*, chapter 7*, § 49. (5).

These regulations relate to vehicle traffic safety management, by limiting the speed of vehicles on different roads, lower than 80 kilometers per hour on expressways and lower than 60 kilometers per hour on other roads. Driving time is restricted as well on expressways, which should not be within the time period from 0 to 6. Night driving can commonly cause fatigue for drivers, by affecting driving conditions due to inappropriate environment, which will cause unwanted consequences during transporting. Overspeed is also one of the main causes that can result in road accidents, which should be taken into consideration. Therefore aiming at enhancing safety management during transporting, these regulations are supposed to be complied with.

"Shippers, carriers and loaders shall formulate inspection and recording systems for road transportation of dangerous goods, as well as safety production management systems such as personnel safety education and training, equipment management, and post operation procedures.

Shippers, carriers, and loaders shall conduct pre-job safety education and training and regular safety education for relevant employees of their units in accordance with the requirements of relevant laws and regulations and the "Regulations Concerning Road Transportation of Dangerous Goods" (JT/T 617). Personnel who have not passed the pre-job safety education and training assessment shall not be allowed to work." (The Government of the People's Republic of China , 2019)*, chapter 1*, § 7.

Safety education and training programs are apparently important for drivers, while relevant personnel who participate in the overall process of transporting should be considered in these programs as well, such as shippers and loaders. In this way, human error can be prevented in a large extent, because educated personnel possess more professional knowledge and can avoid some fatal mistakes.

6.2. Safety Technical Specifications for Commercial Vehicles for Road Transport of Dangerous Goods

These technical specifications determine technical requirements of vehicles concerning dangerous goods transport and are thereby suitable for vehicles that are used for chemical dangerous goods transport.

"Semi-trailer tractors for dangerous goods transportation and dangerous goods transportation trucks with a total mass greater than or equal to 12000 kg should be equipped with Electronic Stability Controller (ESC)." (Ministry of Transport of the People's Republic of China, 2020)*, chapter 6*, § 1. (2).

"The rear axle (non-steering axle) of a semi-trailer for dangerous goods transportation and the rear axle of a dangerous goods transportation truck with a total mass greater than or equal to 12000 kg and all axles of a dangerous goods transportation semi-trailer shall be equipped with an air suspension system." (Ministry of Transport of the People's Republic of China, 2020)*, chapter 6*, § 1. (3).

This ESC is a new active safety system of vehicles and is used for improving the vehicle's stability by detecting and reducing loss of traction, in order to ensure the vehicle under the normal operation. The air suspension system is also used to enhance the stability of the vehicle, by adjusting vehicle height while transporting.

"For dangerous goods transportation semi-trailer tractors and dangerous goods transportation trucks with a total mass greater than or equal to 12000 kg, wheels with single tires should be equipped with a tire pressure monitoring system (TPMS) or a device with tire pressure monitoring function." (Ministry of Transport of the People's Republic of China, 2020)*, chapter 6*, § 1. (4).

"For dangerous goods transportation semi-trailer tractors and dangerous goods transportation trucks with a total mass of more than 3500 kg, the steering wheels shall be equipped with emergency safety devices for puncture, and shall be marked in an easily visible position in the cab." (Ministry of Transport of the People's Republic of China, 2020)*, chapter 6*, § 1. (5).

These technical specifications are related to the safety of the tires on vehicles, by installing TPMS and tire emergency safety devices. In this way, the air pressure inside the tires can be detected while transporting, and the system will alert warnings towards low air pressure of tires and flat tires, which can ensure traffic safety during transport. The tire emergency safety devices enable drivers to control the direction of the vehicle when tires explode, which can guarantee the safety of people in the vehicle.

"If there are safety valves, vent valve components, inspection holes, loading and unloading valves, pipelines and other accessory facilities and equipment on the top of the tank body of tank vehicles, overturn protection devices that meet the requirements of GB 7258 shall be installed." (Ministry of Transport of the People's Republic of China, 2020)*, chapter 7*, § 2. (4).

As for the protection facility on the vehicle, this specification demands the tank vehicles with safety valves and other accessory equipment on the top of the tank body to install overturn protection devices, in order to avoid vehicle overturn while transporting.

"Vehicles transporting category 1, 2.1, 3.4, 1.4, 2.4, 3.5, 1.5, 2 and other dangerous goods with flammable characteristics specified in JT/T 617.2 shall meet the following requirements:
a) Install a static conductive rubber towing zone that meets the requirements of JT/T 230, and the ground terminal of the static conductive rubber towing zone should always be grounded regardless of whether the vehicle is empty or fully loaded. Semi-trailer and

gas fuel semi-trailer tractor should be equipped with static conductive rubber towing zone respectively." (Ministry of Transport of the People's Republic of China, 2020), *chapter 7*, § 4. (3).

These regulations are established for specified vehicles that have flammable characteristics, such as oil tank trucks. The reason for installing the static conductive rubber towing zone is to eliminate static electricity generated by tank trucks during loading, unloading and transportation. Hence static electricity elimination devices must be equipped on the vehicles to avoid sparks caused by static electricity, and thereby the possibility of fire and explosions can be reduced as well. Because tank trucks are usually loaded with flammable and explosive fuel, all open flames or static sparks should be avoided.

6.3. Summary of legislative existing preventive measures

After the descriptions of legislative existing regulations and specifications, this chapter will briefly summarize the legislative existing preventive measures, according to Measures for the Administration of Road Transportation Safety of Hazardous Goods and Safety Technical Specifications for Commercial Vehicles for Road Transport of Dangerous Goods, based on the guidelines of JT/T 617.

As for Measures for the Administration of Road Transportation Safety of Hazardous Goods, safety management towards road safety can be improved after the implementation of this regulation. For instance, clear responsibilities and requirements towards relevant personnel and vehicles should be determined and fulfilled. The speed of vehicles on different roads and the transporting time are also restricted, in order to reduce the number of the accidents, especially on expressways. Safety education and training programs towards all relevant personnel involved in the overall process of transport should be launched, and in this way mistakes from the personnel while driving can be hereby reduced in some degree.

In terms of Safety Technical Specifications for Commercial Vehicles for Road Transport of Dangerous Goods, technical specifications of vehicles are interpretated in order to improve the stability of the vehicle and ensure the people safety, by installing some new technical systems such as ESC and the air suspension system. In addition, the protection devices like the static conductive rubber towing zone on the vehicles with flammable characteristics, can make contribution to the protection level of the vehicle and thereby improve the traffic safety.

All in all, these legislative existing regulations will make a difference in road safety, and with the enforcement of the legislation, the number of chemical dangerous goods transport accidents can be therefore reduced. However, other applicable preventive measures in addition to the legislation should be taken into consideration as well, which is referring to the last sub-question.

7. Stakeholder Analysis

In order to figure out other preventive measures, relevant stakeholders involved in the transporting process should be firstly identified. This chapter will describe different stakeholders that are involved in a project or whose interest are likely to be influenced by the project. When considering stakeholder analysis, evaluating different stakeholders' interest and power is kind of important, since they will have an impact on the decision-making process of the project. Moreover, meeting the requirements and expectations addressed by these stakeholders will help promote a successful outcome of the project. Frequently engaging and communicating with these relevant stakeholders is also a useful way to complete the project successfully, as their decisions may make a difference in the result of the project (Olander, 2007). Moreover, the purpose of this chapter is to find out what kind of stakeholders are involved or affected in the transporting chemical dangerous goods and how they are classified in the stakeholder mapping.

7.1. Stakeholder identification

First of all, stakeholders are necessary to be identified for the project, in order to fulfill their needs and expectations. The mentioned stakeholders are generally defined as individuals or groups that can be involved by the project, or have an interest on the project directly and indirectly (Olander, 2007). Hereafter a stakeholder mapping will be conducted based on the identification of stakeholders, with a power/interest matrix.
The following Table 3 illustrates different descriptions of stakeholders:

Stakeholders	Description
Drivers	Human whose duty is operating vehicles safely.
Transport companies	The company that owns vehicles and is responsible for transporting goods.
Environmental organizations	Organizations that keep an eye on the environment all the time, meaning that any movements or changes towards the environment, including human activities will be traced. The outcomes of these movements and changes will be analyzed as well, such as possible subsequent consequences. And the final purpose of these organizations is protecting the environment and promote sustainable development in the society.
Ministry of Emergency Management	A national authority that provides emergency services as soon as possible when contingencies take place, also responsible for inspecting the safety production of chemical dangerous carriers (like LPG tank) and make sure them meet the basic work safety standards. (Ministry of Emergency Management).

Ministry of transport	A national authority that is in charge of coordinating and managing transport politics. Here in the thesis is referred to road transport of chemical dangerous goods (Ministry of Transport).
Local population	Local population and surrounding dwellings affected by transport accidents.
Media	A means of conveying information to the public, which may increase social attention towards chemical dangerous goods transport and thereby generate the discussion of the topic.
Customers	A target group that the vehicle company is transporting for.
Local road transport authorities	Regional authorities that mainly focus on local transport dynamics and are supposed to respond to any urgent accidents immediately.

Table 3. Identification of stakeholders

Source: Author

7.2. Stakeholder mapping

After the identification of stakeholders, in order to prioritize identified stakeholders and have an overall understanding of their significances and influences, a stakeholder mapping will be demonstrated based on a power/interest matrix. Four categories of stakeholders will be classified clearly in the matrix, with a different level of power and interest (Olander, 2007):

Keep satisfied (high power and low interest):

Consulting these stakeholders in their needs and expectations is the way to carry out in this category, which will keep the stakeholders satisfied and make it easier to obtain their feedbacks towards the project.

Key players (high power and high interest):

These stakeholders are the primary ones who are mainly involved and affected directly in the project, and they are supposed to be taken into consideration at first time.

Minimal effort (low power and low interest):

This group of stakeholders is the least affected and involved, therefore minimal effort can be done in this category of stakeholders. Monitoring and keeping them informed periodically is the right way to execute.

Keep informed (low power and high interest):

This category of stakeholders needs to be informed and updated regarding the progress of the project, which ensures that less conflicts and issues towards the project will exist and to show their considerations to the project.

To be more specific, a stakeholder mapping will be depicted in the following Figure 7, based on power/interest as the two main criteria, and stakeholders are put into four categories as mentioned before:

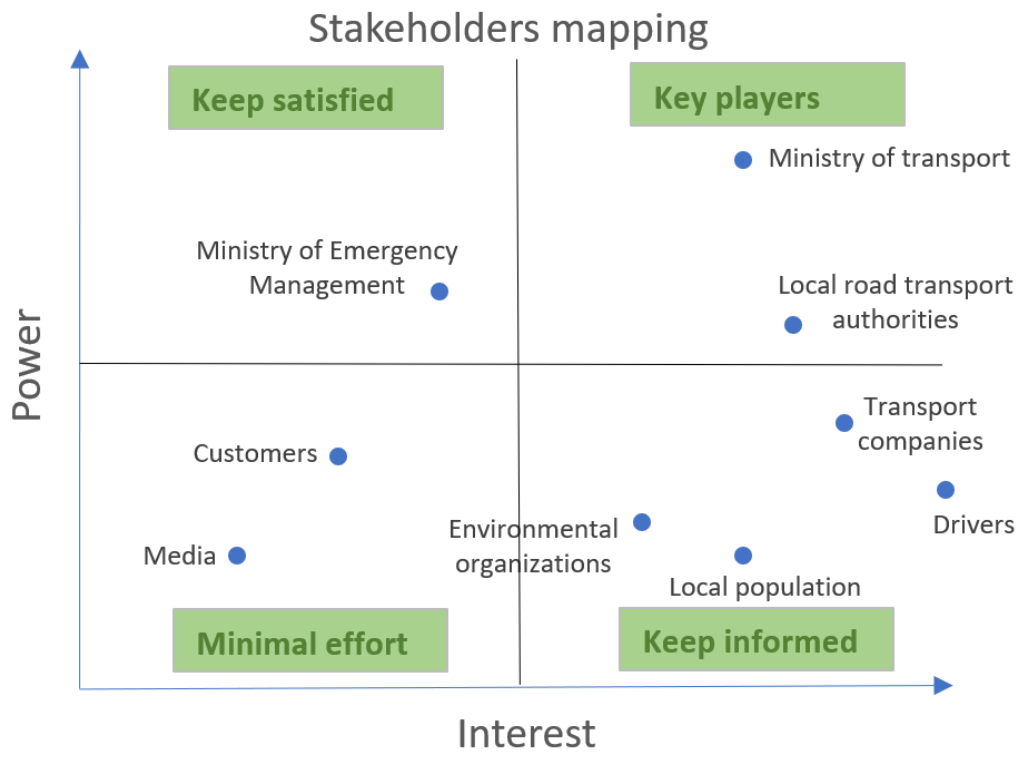

Figure 7. Stakeholder mapping

Source: Author

According to the Figure 7, identified stakeholders are divided into four different categories based on their different level of power and interest. The purpose of this classification of stakeholders is to have a better understanding of each attribute of them, in order to conduct a stakeholder management for the project. In other words, comprehending these stakeholders will benefit in the decision-making process, so that the overall risk of transporting chemical dangerous goods will be reduced in a way, by establishing useful regulations and so on.

Most of stakeholders are distributed into the place of high interest and low power, which indicates that most of them are supposed to be taken into consideration, as well as for those with high power. Among stakeholders *Ministry of transport* and *local road transport authorities* belong to primary stakeholders, which hold high level of power and have a big interest in the project, since both of them are official authorities. While *Ministry of Transport* seems more significant than the other one, as it is responsible for carrying out various transportation projects and it can be also involved in the entire process of transportation.

When it comes to the category of *keep informed*, four stakeholders are put into this place, for their power is a bit lower than the official authorities. Since transport companies take part in activities that are related to the personnel and vehicles, their power is a bit high in a way, followed by the drivers. However, the drivers have more interest than the rest of stakeholders, since they are the ones to manipulate vehicles and can affect or be affected during the entire process of transport. Hence they can be regarded as one of the primary stakeholders. Moreover, there is no doubt for the place of local population and environmental organizations, as they are the group that will be influenced by the transportation activities.

In terms of *keep satisfied* category, *Ministry of Emergency Management* is supposed to be noticed, as they play a significant role in urgent circumstances on road, such as accidents. Thus this stakeholder should be taken into consideration as well and communicated immediately when there is an emergency.

Minimal effort is the category of stakeholders who is the least influential and has the

lowest interest in the transportation. *Customers* of transport companies are placed better than *Media*, because they tend to be more involved in the transportation process.

All in all, some stakeholders in *key players* and *keep informed* category should be regarded as primary stakeholders concerning the transportation process. The reason behind it is that they are more powerful and hold large interests in the transportation activities. In addition, some stakeholders are likely to be related to others when they are making decisions. For instance, the new legislation generated by two national authorities will influence local road transport authorities, which is supposed to enforce the new law in the local regions. In other words, certain changes among these primary stakeholders will not only make a difference in other stakeholders, but also affect the outcome of the transportation process. As a result, they should be prioritized when considering risk management.

8. Theory of planned behavior

After the stakeholder analysis is conducted, one can argue that drivers are supposed to be focused on at first, when figuring out preventive measures towards the chemical dangerous goods transport. The reason behind that is drivers are the personnel who are involved in the entire process of transportation as a carrier of chemical dangerous goods. Although their power is not as high as governmental level or regional level of local road transport authorities, drivers possess the highest interest while transporting, meaning that they are the group that can be affected mostly when there is an emergency or accident. As a result, the theory of planned behavior of drivers will be described in this chapter, which shows the relationships among drivers' beliefs, attitudes, intentions and lastly, behaviors. This theory is kind of psychological approach, since individual's behavior can also be explained and predicted from social attitude and personality trait (Ajzen, 1991).

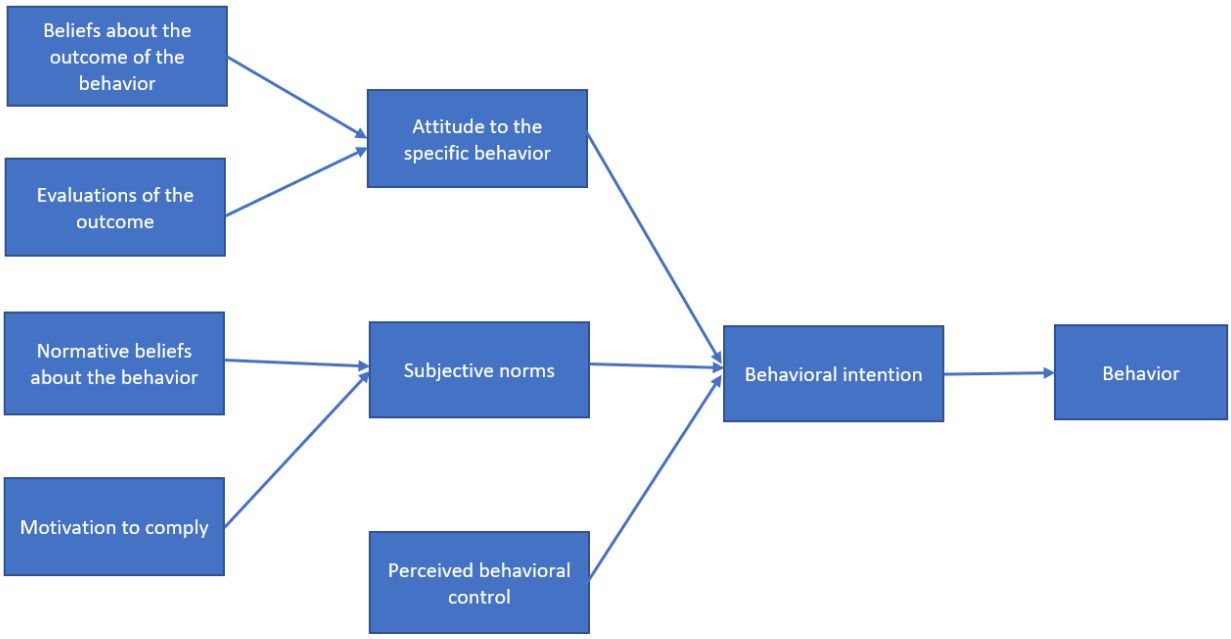

Figure 8. The theory of planned behavior

Source: (Ajzen, 1991)

As can be seen from the Figure 8, the theory of planned behavior approach is introduced along with beliefs, attitude, intention and behavior. In this way, one can see that individual behavior can be influenced by intention, attitude and beliefs. Their relationships are evidently shown in the figure, which is also connected with one and another.

In this case, the behavior can be “drive safely” for the driver carrying the chemical dangerous goods. Therefore, the beliefs about the outcome of the behavior can be “drive safely will reduce the number of chemical dangerous goods transport accidents by road”. Similarly, the evaluations of the outcome can be considered as “the road safety will be hereby enhanced and the chemical dangerous goods transport accidents by road can also be prevented”. The beliefs and evaluations of the outcome will be combined together to interpretate attitude, which can be regarded as a positive attitude towards “drive safely”, meaning that the drivers are willing to perform driving safely.

As for normative beliefs about the behavior, they can be derived from the transport company and family. In other words, the transport company and the driver’s family believe that the driver should achieve this “drive safely” behavior. Motivation to

comply indicates that the driver will comply with the social pressure and behave what the transport company and family believe. As a result, subjective norms are hereby generated with the combination of normative beliefs and motivation to comply. Here subjective norms describe “drive safely” from the driver’s subjective perception, which is influenced by other significant groups (the transport company and family).

Perceived behavioral control can be related to the ease of driving safely for the driver, which means that the driver has obtained professional training programs including safety knowledge and can therefore ensure the personnel safety while driving.

Behavior intention comes into being with the connection of attitude, subjective norms and perceived behavioral control, which can be considered as intentions to drive safely for the driver, leading to the ultimate behavior of “drive safely”.

This approach also illustrates the relationship between attitudes and behaviors, meaning that if the individual attitude towards the behavior is more positive, the intention to achieve the behavior will be more intense. Similarly, positive subjective norms and strong perceived behavioral control will also improve the intensity of the intention of the behavior. In this case, if the educated driver perceives one is able to drive safely, then the driver’s intention of driving safely will be strengthened, which will self-evidently contribute to the behavior of driving safely.

9. Haddon Matrix analysis

In addition to the driver, other stakeholders with high power and high interest should be also taken into consideration. In order to figure out potential preventive measures that these significant stakeholders are able to carry out for the injury prevention, a Haddon Matrix analysis is hereby introduced (Runyan, 1999).

<table>
<tr><th rowspan="2">Phase</th><th rowspan="2">Host</th><th rowspan="2">Equipment</th><th colspan="2">Environment</th></tr>
<tr><th>Physical</th><th>Social</th></tr>
<tr><td rowspan="4">Pre-event</td><td>Lack of training</td><td>Poor vehicle design</td><td rowspan="2">Bad weather conditions</td><td rowspan="3">Legislation and standards</td></tr>
<tr><td>Poor driving habits</td><td>Vehicle overload</td></tr>
<tr><td>Weak management</td><td>Lack of safety device</td><td rowspan="2">Road infrastructure</td></tr>
<tr><td>Poor supervision</td><td>Brake failure</td></tr>
<tr><td rowspan="3">Event</td><td>Failure to use seat belts</td><td rowspan="3">Lack of occupant restraints</td><td rowspan="3">Fire and explosions due to chemical reactions</td><td rowspan="3">Legislation and standards</td></tr>
<tr><td>Collision by other vehicles</td></tr>
<tr><td>Impairments</td></tr>
<tr><td rowspan="3">Post-event</td><td>First aid</td><td>Vehicle redesign</td><td>Road rehabilitation</td><td>Education for first aid</td></tr>
<tr><td rowspan="2">Psychological treatment</td><td>Vehicle periodical maintenance</td><td rowspan="2">Environmental remediation</td><td>Trauma care system</td></tr>
<tr><td>Installation of safety device</td><td>Health insurance</td></tr>
</table>

Table 4. Haddon Matrix analysis

Source: Author

According to the Figure 9, this Haddon Matrix is analyzed from four different aspects: host, equipment, physical environment and social environment, along with the injury intervention and prevention in time of the event from three phases: pre-event, during the event and post-event. In this case, the event in the matrix is referring to the chemical dangerous goods transport accident.

As for the pre-event phase, before the accident takes place, lack of training for the driver, poor driving habits such as alcohol drinking, weak governmental or organizational management, and poor supervision towards the safety production of the vehicle are the factors that will have an impact on the accident, from a host point of view. As for the equipment, poor vehicle design, vehicle overload, lack of safety device and brake failure on vehicles will result in accidents evidently. Physical environment reflects in bad weather conditions and unstructured road infrastructure, while social environment is more associated with legislation and standards.

During the stage of the event, here factors can be regarded as the one that are related to the crash phase of the accident, meaning the exact time point while the accident takes place. Failure to use protection devices such as seat belts, collided by other objects and

individual impairments can be considered as factors in relation to human. Moreover, lack of occupant restraints causing the accident can be a downside of the equipment. For specific vehicles with flammable characteristics, fire and explosions are common to observe during the accident, because of the chemical reactions of the hazardous goods, which will apparently affect physical environment and will take a long time to recover. Besides, social environment here still reflects in legislation and standards, which cannot be changed during the event.

Post-event is the last stage of the matrix, which describes factors that will have an impact on the consequences of the accident. Fast first aid and effective psychological treatment towards the injuries will make a difference in mitigating the consequences of the accident to a large extent for the host aspect. Vehicle redesign, vehicle periodical maintenance and installation of safety device on vehicles are the measures that can be taken from an equipment point of view. In terms of the physical environment, road rehabilitation and environmental remediation after the accident takes place should be focused on, since the well-structured roads and favorable environment are both necessary for the society. With regards to the social environment, education for first aid, trauma care system for the injuries and health insurance are important to be considered, which will alleviate the misery for the injuries and can reduce the economic burden of the injuries' families.

In brief, this Haddon Matrix gives a clear view of factors that are likely to affect the accident from different time points. In this way, intervened by important stakeholders, corresponding injury prevention strategies can be thereby investigated, in order to reduce the number of the accidents and improve road safety in a way.

10. Discussion

This chapter will mainly discuss the sub-questions in the problem statement on the causes of the chemical dangerous goods transport accidents by road, legislative existing measures and other applicable preventive measures that can be taken in order to reduce the risk of transportation.

The risk assessment indicates fundamental causes and direct causes that can result in the accidents from four different aspects: organization, human, vehicle and environment. The fundamental causes mainly reflect in lack of safety awareness, which can be also related to the organizational perception towards the severe consequences of the accidents (Wen, 2019). For most of organizations, the management levels disregard the safety awareness of transportation, leading to a negative consequence that the drivers and other personnel are lack of the safety knowledge. As a result, issues regarding low education level, low comprehensive quality and poor safety awareness of the personnel have arisen.

Moreover, imperfect market mechanism in the transport industry will also result in accidents. This is due to low barriers of the market entrance and intensive competition among transport companies. Although the number of transport companies has climbed up these years, the size of the companies is commonly small, meaning that in order to obtain the market share, some of them lower the price of the transportation. In this way, the competition in the market will be self-evidently intensified and it will have a negative impact on transport to a large extent. This finding can be also supported from the interview towards the driver in the industry (Wen, 2019).

Direct causes of the accidents are mostly attributed to human, vehicle and environment, which are the main direct risks during transportation. Human error compared to other three aspects should be considered as a matter of priority, since it can be the most unstable influence in transport and can be easily affected by other factors, such as external weather conditions. For instance, one can argue that personality trait and personal habits can have a big influence in attitudes of the drivers (Statistical analysis and preventive measures of hazardous chemicals transport accidents from 2013 to 2017,

2019). In other words, if a driver is used to alcohol drinking before driving, the possibility of the accidents will be apparently high and the occurrence of the accidents will be increased. However, if the overall personnel are well educated concerning driving and safety knowledge in the chemical dangerous goods transportation, the number of the accidents will be remarkably reduced. In order to achieve that, preventive measures towards the accidents are recommended to be concentrated.

Existing legislation and regulations make a significant contribute in standardizing the industry and integrating the official standards in the industry, which can be regarded as existing preventive measures. With the help of these regulations, transport safety management in various aspects can be therefore enhanced, which will promote road safety and occupational health and health of the drivers in a way.

However, although the new legislation and regulations are set up, other preventive measures in addition to legislation are recommended to be focused on. The legislation emphasizes the control towards the participants during the transportation, whereas a large number of transport companies are still indifferent to it and have no professional qualifications for transport (Zhu, 2020). Therefore, these other preventive measures will play an important part in accidents prevention.

Primary stakeholders are identified at first, so that it can give a clear direction of who are mainly responsible for preventing accidents. For instance, transport authorities are supposed to put effort in improving the existing road transport system, meaning that specific staff should be appointed to manage the vehicles carrying hazardous chemicals while transporting and inspect them, in order to make sure they are complied with the relevant standards and regulations. As for the transport companies, it is their responsibility to ensure the qualifications of the personnel and vehicles. To achieve that, safety education campaigns can be implemented every time before the departure, so that every personnel will have a good command of safety knowledge. Other than that, more than two drivers are suggested in the vehicle for the long-distance transport, and they can take turns in every four hours or six hours, in order to prevent fatigue while transporting (Zhu, 2020).

Furthermore, drivers are considered as part of primary stakeholders, although their power towards decision making is not that much high. Another interesting point for the drivers is that their attitudes can influence their behaviors, and their attitudes can be affected by the judgment of others who are important for them. Thus their behaviors can be influenced by changing their attitudes, to a safe driving orientation, which will need the effective actions and effort from relevant organizations, including the government and transport companies.

A report has stated that behavioral strategies can have a positive effect on injury prevention and improve road safety in a way. One can argue that contingency management can be applied with different rewards and incentives in the transport companies. In this way, the driver's attitudes towards the accidents can be positively influenced, meaning that they will pay more attention to accident prevention, and thereby their behaviors will be affected as well in a safer way (Sleet, D.; Lonero, L, 2020).

Moreover, the improvement of the safety management in the organizations can also make contribution to improve the safety culture in the company, which will in a way impact the personnel's attitudes and behaviors. This can be achieved by implementing effective safety training education programs and safety regulations. As a result, the personnel in the organizations will hold positive attitudes towards the accidents, which will make a difference in safe behaviors. In this way, the risk of transport can be reduced and the accidents can be effectively prevented (Tam, Vivian W.Y,; Fung, Ivan W.H, 2012).

11. Conclusion

In conclusion, this thesis highlights the issue of the accidents regarding the chemical dangerous goods transport by road in China, which has also triggered the attention from the society due to their severe consequences in recent years. The main causes of the accidents are founded in organization and human aspects, compared to vehicle and environment. As a result, the key point for the purpose of reducing the accidents should be put on (1) the drivers, (2) transport companies and (3) the government.

After the occurrences of large accidents in chemical dangerous goods transport, the legislation and regulations were established to formulate official standards in the industry. In this way, traffic safety, road safety and personnel safety can be improved, which will ultimately result in decreasing the risk level in the transportation sector.

Besides legislation, other preventive measures should be taken into consideration, to reduce the number of the accidents and mitigate their consequences. As for the government, the inspection system towards different roads, equipment on vehicles and the quality of chemical dangerous goods should be developed. This can be implemented with the participation and enforcement of administrative departments such as Ministry of Transport, local road transport authorities etc.

In addition, improving safety management in transport companies also plays a vital role in countermeasures, including the installations of useful protection measures, application of new technologies and offering safety training programs or so. In this way, the attitudes of the drivers will be influenced and ultimately their behaviors can be affected in a positive way. In terms of dealing with the issue of intensive competition among transport companies, safety management is also significant for them, and the market mechanism is likely to be well structured under the help of the government and transport companies.

All in all, by understanding the causes of the accidents and the recommendation of preventive measures, safety awareness of the personnel and organizations can be ensured to a large extent. Consequently, the accidents are likely to be prevented and the risk level of chemical dangerous goods transport will be reduced to an acceptable level.

12. Future work

This thesis mainly focuses on the causes and preventive measures towards the accident in the chemical dangerous goods transport, besides that, a further study concerning the new risks that might arise in relation to the transportation after the implementation of preventive measures can be also considered. In other words, risk monitoring during the entire process of transportation is necessary to be incorporated.

Digitalization in the chemical dangerous goods transport is the modern trend in the industry, which adopts new internet technology such as big data (Sun, 2020). In this way, the entire process of transporting can be transparent at any time and the supervision towards both vehicles and drivers will be strengthened, which makes it easier for risk monitoring.

In brief, one can argue that the application of digitalization can be beneficial to the whole industry, and the efficiency and safety of the transportation will be boosted to some degree.

Furthermore, in order to achieve the risk monitoring, more interviews and questionnaires towards the drivers can be done, in order to understand their perceptions of the accidents. Based on the results from interviews and questionnaires, the safety culture can be more easily promoted. In this way, the overall risks of transport can be reduced and the accidents will be thereby prevented.

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Appendix: Glossary

Risk:

According to ISO 31000, risk is defined as following:

"effect on uncertainty on objectives" In the ISO standard, three notes are added, stating that an effect is a deviation from the expected. It can be positive, negative or both, and can address, create or result in opportunities and threats." (ISO 31000:2018).

In this thesis, risk is regarded as a negative effect that is likely to cause danger, death, injury and other harmful consequences, since the topic of the thesis is associated with accidents, that can evidently lead to adverse consequences.

Consequence:

The outcome of an event and it will have negative effects on relevant objectives such as human, facilities and the environment (International Organization for Standardization, 2018).

Chemical dangerous goods/Hazardous chemicals:

Highly toxic chemicals and other chemicals with characteristics of toxic, corrosive, explosive, flammable, combustion-supporting that are harmful to human, facilities and the environment (The Central People's Government of the People's Republic of China, 2011).

Vehicle:

Motor vehicles that are used for transporting chemical dangerous goods, such as articulated vehicles, semi-trailers etc. (Ministry of Transport, 2018).