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The research on risk evaluation of Shanghai LNG import program

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THE RESEARCH ON RISK EVALUATION OF SHANGHAI LNG IMPORT PROGRAM

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

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ABSTRACT

Title of research paper: **The research on risk evaluation of Shanghai LNG import program**

Degree: **MSc**

With the rapid development of China's economy, the demand of energy increased drastically especially in coastal area such as Shanghai. LNG as a clean, high efficiency and low price energy is very suitable for satisfying the increasing demand of energy in China. But the annual output of Chinese gas field is not enough to satisfy the annual demand. And it is reported that in the year of 2010, the demand of natural gas of Shanghai will be about 6 billion cubic meters. However, the annual supply volume is below 3 billion cubic meters. So the government approved several LNG import programs to fill this gap. And the Shanghai LNG program is approved after Guangdong and Fujian program. So this dissertation is worked out under this background. And the marine transportation of LNG is the key link of the LNG importation. Although the LNG carriers have a good reputation in the history of operation, the fatalness of LNG should not be under estimated. Once LNG leased and exploded, the result will be very terrible. So it is very important to keep LNG carriers safe.

The dissertation first discusses the characteristic of LNG and LNG carrier. Second on the base of analysis of the characteristic of Shanghai LNG import program, the article mainly discussed the risk that will appear in the process of the LNG import chain. Third, in this article, the author used two methodologies to carry out the quantitative

analysis of the security problems in the trade of LNG. And this will provide the mathematic support to the project of importing LNG. At last, the article discussed the precaution that Shanghai LNG program can take to avoid the risks.

Key words: Shanghai LNG Program, Risk Evaluation, Delphi Method, Fuzzy Comprehensive Method

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LIST OF ABBREVIATIONS

CIF	Cost，Insurance and Freight
CNOOC	China National Offshore Oil Corporation
FOB	Free on Board
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
RMB	Renminbi
USD	U.S.Dollar

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Chapter 1 Introduction

1.1 The Background and Importance of the Topic

With the rapid development of China's economy, the demand of energy increased drastically. Nowadays, because coal is the main energy that consumed in Southern China which is far away from the China's base of energy production, the pressure of the transportation and environment protection is very huge. And even our country imports amounts of LPG every year to ease the pressure; however, in the long run the resource of LPG is very limited and we must find other energy as substitution. So in this situation LNG will be the focus objectives that China will exploit in the future due to its characteristic of clean, high efficiency and low price. But our LNG industry lags behind the world, the consumption of the LNG only take 1.9% in the total energy consumption. It is much lower than the average level of the world (23.2%) and the Asia (8.8%). Although we had discovered and developed several large gas fields, it is hard to satisfy the demand of the LNG of the Southern China. On the contrary, the resource of natural gas is very abundant and the proved reserves can support the consumption and production for 65 years. The international energy market provides the possibility for our country to import the natural gas. So we should import the LNG from the world market while exploiting the domestic gas field.

The project of importing LNG had been decided by Chinese government in the year of

1998. And the first LNG receive station was established at 2006 in Shenzhen. Nowadays there are 22 programs to be built or approved in China. These programs are usually located on the coastal areas of China.

The importation of the LNG is a big project relating home and abroad. The operation of the LNG shipping companies needs huge investment and long cycles. And the transportation market is easy to be affected by the world economy and political factors. Due to profound and lasting influence of the LNG shipping companies, the companies need to analyze the possible risk.

1.2 Literature Review

The first economist who researched the risk is Dr. Allan.H.Willet. Willet (1901) pointed out in his thesis that the risk is the objective reflection of the uncertainty of the things that do not be wished to happen. And after 20years, Knight (1921) believed the risk is not the common uncertainty but the gauge ably one. He pointed out that the risk of economy can be calculated and predicted by the mathematical statistics.

LNG is odorless, colorless, non-corrosive and nontoxic. LNG is stored in double-walled, well insulated tanks at atmospheric pressure and 112 K. LNG will burn if it is mixed with 5–15% air. LNG is primarily comprised of methane with small proportions of ethane, propane, butanes and nitrogen. The liquefaction of natural gas requires the removal of the non-hydrocarbon components of natural gas such as water, carbon dioxide and hydrogen sulfide to prevent from corrosion or forming solid.

LNG is principally used for transporting natural gas to markets, where it is degasified and distributed as pipeline natural gas. LNG offers an energy density comparable to

petrol and diesel fuels and produces less pollution, but its relatively high cost of production and the need to store it in expensive cryogenic tanks have prevented its widespread use in commercial applications. It can be used in natural gas vehicles, although it is more common to design vehicles to use compressed natural gas.

Javanmardi (2006) point out that there are three types of LNG carrier: the spherical design (moss), the membrane design and structural prismatic design (IHI SPD). Nowadays the moss type takes 52% of LNG carriers; membrane type takes 43% and structural prismatic type takes 5%. A typical LNG carrier can transport about 125,000 m3 of LNG which equals to about 74–82 million standard m3 of natural gas. Usually a typical carrier is 275 meters long, 43 meters wide and 11 meters in water draft and costs about $170 million. The cost of LNG vessel depends to a large extent on the LNG boiling off rate, reliquefaction system and size of the ship.

Yi Jing (2002) showed the special structure of the LNG carrier. Due to the extreme low temperature of LNG, the cargo hold must use the heat insulating material such as fiber glass and balsa wood. And the LNG carrier must apply double hull and secondary shielding so that the LNG would not leak out of the cargo hold.

And recently there is a trend that the membrane types are more welcomed than the self supporting storage systems. The reason is that prismatic membrane tanks utilize the hull shape more efficiently and thus have less void space between the cargo-tanks and ballast tanks. As a result, moss-type design is far more expensive than the membrane design to transit the Suez Canal when the two types of ships have the same capacity. However, the security of self-supporting tanks is better than membrane tanks and has greater resistance to sloshing forces. And this type of LNG carrier maybe is used in the future for offshore storage where bad weather will be a significant factor.

Ji Haizong (2004) believed that China must develop its natural gas industrial and there are three reasons. First, importing LNG can assure our national energy safety. Nowadays, with rapid development of Chinese economy, the demand of energy increased sharply. And the supply of crude oil and coal become more and more strained. So importing LNG can ease the pressure of energy supply. Second, importing LNG can stimulate the development of shipping industry. There is an unwritten rule that a shipping company can become the first class company only when it can transport LNG. The transportation of LNG had already become the benchmark of the strength of the shipping company. If Chinese shipping company can take the technology of building LNG carrier, it will increase the national shipping strength and improve the development of the correlation industrial cluster. Third, developing LNG industry can control the cost of transportation and assure good income. There is a "take or pay" term in the contract of LNG trade which means the buyer must pay the money even he can not receive the cargo. So the income of LNG transportation is very considerable.

Although developing LNG industry has a bright future and good benefit, Gaofeng (2000) pointed out that the importation of LNG by sea will face several risks. One of the risks is the sellers of LNG can not supply the sufficient cargo on time. For example, the exploitation equipments can not work for a period of time. And the unstable domestic political situation will affect the supply of LNG. Another risk is the buyer of LNG can not receive the arrived cargoes. For example, the price of LNG is higher than other kinds of energy such as nuclear power or LPG. In this situation, the demand for LNG will decrease and buyer would not receive the arrived cargo. And this will lead to great loss for importer.

So in order to prevent these accidents happen, we should analysis the reasons caused

the accidents. Erik Vanem (2007) used Fault Tree Methodology (FTA) to analysis all initiating events for each risk. First, he did the frequency of the initiating events. He pointed out that there are 5 major accident scenarios which are collision, grounding, contact, fire and explosion and leakage of LNG. Second, he did consequence assessment by utilizing event tree techniques. In this part, a set of event trees will be constructed. Then, these event trees will be quantified using a variety of different techniques for different branches. Finally, he get the results.

And Qian Yuan (2008) used Fuzzy Theory and Entropy Theory to evaluate the risk of operation. He said many factors that influence the risks of shipping company are uncertain and fuzzy. So we should not abandon some factors that are very important but hard to be quantification. And the fuzzy comprehensive evaluation is method that can evaluate completely the complex things. This evaluation not only has the strict quantitative analysis but also has qualitative description of the fuzzy phenomenon. The characteristics of fuzzy comprehensive evaluation are: first, this method can not rely on a specific index and it compares the indexes to avoid the deviation. Second, this method establishes the organic link among the non-quantitative requirements so that it can evaluate the entirety characteristics and the general trend.

As to the suggestion to the management of LNG carrier, Erik Vanem (2007) believes that the safety of LNG carrier is related to navigational safety, maneuverability, collision avoidance, cargo protection, and damage stability and evacuation arrangements. To improve the quality of seamen is the key point. And imply the rules or regulation made by IMO is also very important. Meanwhile the governments or port authorities should enhance the management of LNG terminal. Gao Feng (2000) also gave some suggestions to Chinese shipping company. He said that the imported LNG should carried by Chinese shipping companies in order to protect national welfare.

And the trade term should be FOB instead of CIF or DES so that we can arrange the transportation. Due to the lack of the experience of managing LNG carriers, it is better to establish a joint venture rather than sole-funded company.

1.3 Methodology

Because many factors that influence the risks of shipping company are uncertain and fuzzy, we should not abandon some factors that are very important but hard to be quantification. And the fuzzy comprehensive evaluation is method that can evaluate completely the complex things. This evaluation not only has the strict quantitative analysis but also has qualitative description of the fuzzy phenomenon. The characteristics of fuzzy comprehensive evaluation are: first, this method can not rely on a specific index and it compares the indexes to avoid the deviation. Second, this method establishes the organic link among the non-quantitative requirements so that it can evaluate the entirety characteristics and the general trend.

And in order to use fuzzy comprehensive evaluation, we need to decide the weight of each index. Nowadays there are several methods to decide the weight. They are divided into two kinds which are subjective empowerment method and objective empowerment method. Delphi method, Analytic Hierarchy Process and Frequencies Analysis are belonging to the subjective method. Principal Component Analysis and Entropy Method are belonging to the objective method. The SEM mainly relies on judgment of experts and then uses different methods to empower the index.

LNG program is a very complex system. There are so many factors that affect its operating risks. What is more, most of them can not be represented by the function though quantitative method. Analyzing these factors must rely on the experience of

experts. So we select Delphi method to decide the weight of the indexes.

1.4 Organization & Structure of the Dissertation

The aim of this dissertation is to use the fuzzy comprehensive evaluation method and Delphi method to evaluate the risk that Shanghai LNG import program will face. There are four chapters in the main body of dissertation. In chapter 2, the author analyzes the characteristics of different types of LNG carrier. This is the base of the dissertation. In chapter 3, the author analyzes the several risks that Shanghai LNG import program will face. Then the author provides some suggestions to avoid or lower these risks. In chapter 4, the author explains the process of fuzzy comprehensive evaluation method and Delphi method. And also the author establishes the risk evaluation model for Shanghai LNG program. In chapter 5, the author puts the data into the model and gets the final results. Though the dissertation, the readers should clearly understand that which kinds of risk Shanghai LNG import program will face and the probability of each risk appears. Also they can know what method can be used to avoid these risks.

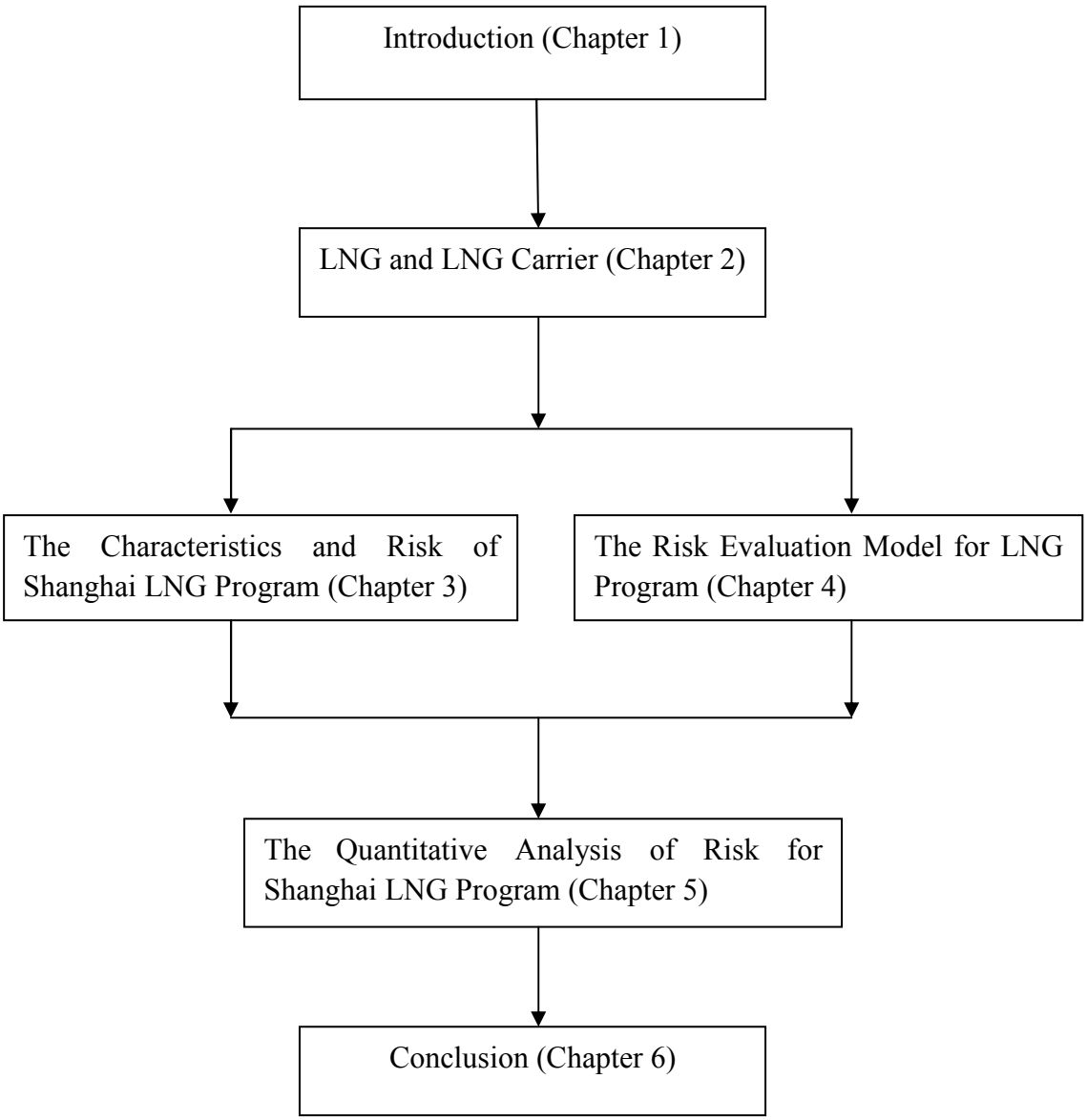


Figure 1.1 the structure of the dissertation

Source: Drawn on my own

Chapter 2 LNG and LNG Carrier

2.1 The Nature of LNG and Its Purpose

LNG is odorless, colorless, non-corrosive and nontoxic. LNG is stored in double-walled, well insulated tanks at atmospheric pressure and 112 K. LNG will burn if it is mixed with 5–15% air. LNG is primarily comprised of methane with small proportions of ethane, propane, butanes and nitrogen. The liquefaction of natural gas requires the removal of the non-hydrocarbon components of natural gas such as water, carbon dioxide and hydrogen sulfide to prevent from corrosion or forming solid. Liquefaction of natural gas reduces its volume by approximately 600 times.

LNG is meanly used as fuel and it is characteristic of high caloric value, cleanness and cheap price. So it is more competitive than coal and oil. And the civil users are usually citizens, catering industry and glass work. Further more, the LNG can be used as the raw material of fertilizer, plastic and adhesive.

2.2 The Characteristic of LNG Carrier

Due to the above characteristics of LNG, the cargo holds of LNG carriers should be special designed.

2.2.1 The General Characteristic of Structure

1. Using low temperature material

According to the IGC code, the material that used to build the LNG carriers must endure the temperature of -168 °C. So the designers usually select the special material such as 9% nickel steel, Austenite steel, Aluminums alloy and Austenite iron-nickel alloy.

2. Applying the secondary shielding

According to the IGC code, the secondary shielding must hold the leakage of primary shielding for at least 15 days. The reason is the LNG carrier would not use more than 15 days from the loading port to the discharging port. Table 2.1 list the requirement of cargo holds.

Table 2.1 the requirement of cargo holds to the secondary shielding

The temperature of the cargo (standard atmospheric pressure)	Above -10°C	Between -10°C and -55°C	Below -55°C
General cargo holds	No requirement for secondary shielding	The hull can be used as secondary shielding	Independent secondary shielding
Membrane type			Completed secondary shielding
Semi-membrane type			Completed secondary shielding
Moss type A			Completed

			secondary shielding
Moss type B			Partial secondary shielding
Moss type C			No requirement for secondary shielding

Source: Information obtained from internet

3. Applying double hull

In order to prevent and lower damage to the cargo hold of the LNG carrier when it met collision and grounding accident, all the vessel must apply the double hull.

4. Using insulation material

The performance of the insulation material is very crucial in the liquid tank of LNG carriers. It influences the rate of evaporation and the pressure of cargo. And in some designs the insulation layer is also the part of the supporting section. So the bearing capacity is very important when selecting the insulation materials. And the insulation materials that are much used in the construction of the modern LNG carriers are foamed polystyrene, polyurethane foam, fiber glass, light wood and other materials.

Table 2.2 the insulation material of LNG carrier

Heat insulation material	Relative density	Heat conductivity	Allowable temperature (°C)
Foamed polystyrene	21-25	0.024-0.038	70
Polyurethane foam	27-52	0.027	120
Foam glass	170-180	0.042-0.052	450

Fiber glass	8-120	0.028-0.032	300
Amianthine	67-200	0.032-0.036	400
Light wood	118-186	0.034-0.039	130

Source: Information obtained from internet

2.2.2 The Characteristic of Different Cargo Holds

The most notable characteristic of the LNG carrier is that the maintenance system is very different. Its cargo holds can protect the main construction against the brittle failure. And the cost of the holds usually takes 25% of the total cost of the vessel.

In the history of the development of LNG carrier, there are at least 15 maintenance systems and they belong to two basic type: independent type and membrane type. The independent type includes the liquid tank that independent from the hull. These tanks can support the weight of itself and static/dynamic load generated by the liquid cargo. And the support section of the tank will transfer the load to the main structure of the vessel. The membrane type tanks are made of metallic films and can adhere to the hulls thought the insulation layers.

The total length and the shape of the LNG carriers are decided by the shape of the cargo holds. The technical problem is the most complex in the all kinds of vessels. And the design of the structure of liquid tanks will influence the economy and security of the ship. So when building the vessel the optimum design should be decided from the aspects of structure, material and intensity.

Here we will set forth the advantages and disadvantages of the different types that is most used in the LNG cargo holds.

1. Conch type

The conch type vessel is the pioneer of the LNG marine transportation and the represent vessels are the “Methane Princess” and “Methane March”. The main heat insulation layers of these two ships are still in good condition. The cargo holds of conch type is prismatic mode.

Advantages: it can make better use of the volume than spherical cargo holds. And the cargo’s center of gravity is low and the stability is good. In the prismatic cargo holds, there are horizontal and vertical swage bulkheads. So this can reduce the free surface of liquid.

Disadvantages: the cost of the material of the main heat insulation layer of this type cargo holds is more expensive than others. And when do the repair work by welding, it may damage the main heat insulation layer.

2. Moss type

The structure of this type is the spherical structure. It was much used in the LPG carriers and then it was introduced to the LNG carriers. The body of this spherical liquid cargo holds is welded on the vertical cylinder pillar. This pillar connects with the bottom of the ship and the cargo holds can expand or contract freely. So all the offset dimensioning caused by the distortion can be absorbed by the space between the tanks and bottom.

Advantages: the spherical tanks only need partial secondary shielding. And its

requirement for heat insulation is not so strict while its shape is easy to analyze the structure. The building technology is simple due to no inside stiffener. And if the cargo pump goes wrong, it is easy to press the cargo holds to discharge the LNG urgently.

Disadvantages: the space utilization rate of the vessel is quit low. And in order to carry the same volume of cargo, we need to lengthen the total length of the ship or heighten the height of liquid tanks. However, the total length of ship is the key factor that influences the cost of vessel. So the longer the ship is, the more expensive it will be. And in the ship of Moss type, the centre of gravity is higher than other ships and the stability is worse. Moreover, the upper cover of the spherical tanks will affect the view of the bridge and the premium of the ship may be higher.

3. Membrane type

This system uses a layer of thin metal plate as the main bulkhead and reinforce it though the heat insulation layer.

The most advantage is the very low construction cost, high space utilization rate. The membrane type uses very few low temperature materials so it can use the hold space very efficiency. It requires little quantity of inert gas and little LNG can cool the cargo holds in short time because of the light weight of the main heat insulation layer. Besides, it does not need so many heavy lifts to set the main layer so that the set work would not disturb the other work. However, there is no possibility to do the structure analysis to the membrane ship.

The reason is that there are two heat insulation layers and they can not be entered. And if the structure of the ballast tank damaged, the water will permeate into the secondary

shielding though the heat insulation layer. It is very hard to repair it and the cost will be very huge. What's more, the inherent defect of the membrane type is that it is easy to be damaged by the liquid movement especially in the situation of half load or in ballast. It would threaten the security of the vessels which route includes many ports.

The membrane type can be divided into two modes: Gaz-Transport mode and Technigaz mode.

(1). Gaz-Transport mode

The primary and secondary shielding of this mode is made by the nickel steel of 0.5 mm- 0.7 mm. The space between these two insulation layers is filled by the wooden cases which are full of perlite powder. This can reduce the weight of the vessel and it is one of the most economic modes. The GZ mode is easy to be applied in all kinds of the ships and the represents are "POLAR.ALASKA" and "ARCTIC.TOKYO".

The disadvantages of this mode are: it is easy to be damaged by the cautery and the mechanical effect. The shock of the dynamic load of the ship will damage the cargo holds. And it will be impossible to survey its heat insulation layers when the vessel is being operated.

(2). Technigaz mode

This mode is designed by the French Industrial Gas Company. The membranous material is aluminum alloy plate and the insulation material is foamed polyethylene. The corrosion-resisting stainless steel is used as the cushioning material of the interlayer. The voyages for ages had proved this mode is very successful.

The disadvantaged of this mode are: in the period of construction, there will be so

many places to be welded. And also it will take a lot of time to do the test.

4. Semi-membrane type

The structure of this type of liquid tank is between the spherical type and membrane type. The membrane used as its main bulkhead is much thicker than the membrane type. And the corner of it is designed as round so that it can support the expansion or shrink of itself. This type is the independent when the tank is empty and it will be the non-independent when the cargo hold is loaded with LNG. The pressure of the liquid and vapor that act on the main bulkhead can be transferred to the inner hull though the heat insulation layer. Due to the thick bulkhead, it can realize the automatic double sided weld and the X-ray inspection. But the vessels that apply the semi-membrane system usually have less capacity.

2.3 The Analyze of Worldwide LNG Fleet

Comparing to other types of vessel, the LNG fleet is rather small. According to the data from Clarkson, there are 305 LNG vessels. (See table 2.3).

Table 2.3 LNG carrier fleet by year of build

Year of Build	**Fleet Nos. and '000 Cbm.**											
Size Cbm.	**up to 19,999**		**20-59,999**		**60-99,999**		**100-139,999**		**140,000+**		**T O T A L**	
<= 1979			6	234	11	849	23	2,910			40	3,993
1980							4	509			4	509
1981							5	651			5	651
1982							1	130			1	130
1983							3	377			3	377
1984							4	510			4	510
1985							1	126			1	126

1986												
1987												
1988	1	2									1	2
1989							3	383			3	383
1990							2	264			2	264
1991							1	128			1	128
1992							1	127			1	127
1993	1	19			2	180	2	255			5	454
1994							9	1,167			9	1,167
1995							4	536			4	536
1996	1	19					6	804			7	824
1997	1	19			1	65	5	677			7	761
1998	1	19			1	65	3	406			5	490
1999							5	684			5	684
2000			1	23			13	1,777			14	1,801
2001							1	137			1	137
2002							9	1,229	1	141	10	1,369
2003	1	3					12	1,654	2	288	15	1,945
2004	1	1					16	2,204	5	725	22	2,930
2005	1	3					5	689	13	1,884	19	2,576
2006					1	74	2	273	25	3,651	28	3,998
2007	1	19			1	74	1	138	29	4,567	32	4,799
2008					1	76			50	9,029	51	9,104
2009									5	1,030	5	1,030
T O T A L	**9**	**103**	**7**	**257**	**18**	**1,383**	**141**	**18,747**	**130**	**21,315**	**305**	**41,805**
AVG. AGE	**9.5**		**32.5**		**25.0**		**14.8**		**1.6**		**10.1**	

Source: Clarkson Liquid Natural Gas Carrier Register 2009

And these ships are belonging to about 40 companies. The biggest company is the joint venture invested by NYK, MOL and K Line. The second big company is ADNOC of United Arab Emirates. The third company is IGTC from Australia.

From the table, we can find that the average age of LNG carrier decreases with the increase of capacity. This reveals that the trend of development of LNG carrier is maximize. And also it reveals that the average age of vessel will continue to decrease

with the delivery of more and more LNG ships.

Nowadays the LNG carriers are mainly MOSS type and Membrane type. And Moss type takes about 52.2% of the total fleet and Membrane type takes 39.6%. The other type takes 8.2%.

So finally we get the conclusion that the trend of LNG carriers is as follows:

1. The vessel becomes larger and larger. The main stream is the ships which capacity is above 125 thousand cubic meters.
2. The Moss type will still be the dominate positions. Due to the relative low cost and high stability, Moss type is chosen by many ship owners.
3. The life length of LNG carrier is extended. The LNG carrier has a long operational life because of the clean cargo and low deterioration. There are still many vessels in the market which were delivered in 1970's. And some owners even wish the life of LNG carrier can be extended to 50 years so that to operate for 2 periods contract.

Chapter 3 The Characteristics and Risk of Shanghai LNG Program

3.1 The Overview of LNG Program

3.1.1 The Current Situation of Chinese LNG Import Program

Nowadays with the rapid development of Chinese economy, the energy supplies become a bigger and bigger problem. So Chinese government put more and more emphasizes on the development of LNG industry. In the end of 1999, Chinese government authorizes the phase 1 of Guangdong province LNG import project. This starts the whole project of importing LNG of China. Then, in February 2003 the government approves the LNG import program of Fujian province and it became the second formally started program in China. After then, three oil companied of China carried out the prophase research work in the coastal area of China. And besides these three major programs of China, there are 19 LNG import programs to be approved. These programs will locate in 19 cities such as Hainan, Qingdao, Jiangsu and other province.

And nowadays small-scale LNG plants and LNG satellite gasification stations also get sudden rise. China has established more than 100 LNG satellite gasification stations since the first station was put into use in Shandong province at December in the year of 2001. Most of these stations are distributed in developed cities in southeast and

southern China. Nowadays, there are dozens of cities where has the LNG gasification station. And the whole market capacities has reached $500\times10^4 m^3$ / d.

3.1.2 Shanghai LNG Import Program

After these two programs there came the program of Shanghai. It is reported that in the year of 2010, the demand of natural gas of Shanghai will be about 6 billion cubic meters. However, the annual supply volume is below 3 billion cubic meters. So the Shanghai LNG program is approved to make up for this gap. And the program of Shanghai will be divided to two phases. The phase 1 is estimated to import about 4 billion cubic meters. This program is carried out by the Shanghai LNG Corporation. This company is a joint venture founded by CNOOC and Shenergy Corporation this program in 2004.

The gas source of Shanghai LNG program is Malaysia. In the July 31th 2006, Shanghai LNG Corporation signed the trade contract with Malaysia third LNG Corporation (Peronas). Malaysia will supply LNG to Shanghai from the year of 2009. And the supply volume will increase to 3 million tons from 1.1 million tons in the year of 2012 when the program will be total completed.

Shanghai LNG program includes three main projects: first is the receiving station. It locates in an island in the eastern port area of Xiaoyang Shan. There will be three 160 thousand cubic meters LNG storage tanks. And three LNG unloading arms and other facilities will be installed. The total floor space is 39.6 hectares which includes the space for the phrase 2. Second is the LNG carrier exclusive terminal and the supporting facilities for the heavy cargo terminal. The LNG carrier exclusive terminal is designed to take the vessels of 0.8 to 2 million dead weight ton. Third is benthal

pipeline. Though the pipeline of 40 kilometers, natural gas will enter into the main gas network of Shanghai. And the transportation will be carried out by both Malaysian third LNG Corporation and China LNG Shipping Corporation. In other words, each company will transport 1.5 million tons LNG annually. Meanwhile China LNG Shipping Corporation had ordered 5 LNG carriers and 2 of them will be exclusive used for Shanghai LNG program. And the volume of these 5 carriers will be 1.47 million cubic meters.

Now the phase 1 had been finished in the early 2009 and it is being tested for the formal commercial operation.

3.2 The Characteristics of LNG Program

3.2.1 Huge Investment

The working procedures of LNG include liquefaction, low temperature storage, low temperature transportation and degasification. So it has a special international trade chain. The process of it is usually: gas fields- LNG liquefaction gas stations- LNG carriers- LNG receiving stations- users. Generally speaking, this chain can be divided upstream, midstream and downstream three sections. Take Guangdong LNG program as an example. The investment of each section is stated as table 3.1.

Table 3.1 the total cost of Guangdong LNG program

	Program	Cost (in billion USD)
Upstream	Gas field development	1~2
Midstream	LNG equipments and port facilities LNG storage tank, receiving stations	2~3 0.4~0.5

	Main gas pipe lines	0.3~0.4
Downstream	Power plants	3~4
Total cost	(600 million tons/year)	6.7~9.9

Source: Information obtained from internet

It is reported that the construction of Shanghai LNG program phrase 1 costs nearly 7 billion RMB.

3.2.2 Oriented Shipbuilding

When shipping company expands its fleet, it usually will consult the market analysis or the forecast. But the construction of the LNG carriers can not base on the supply and demand or the forecast of the future. Nearly all the LNG carriers are constructed for specific projects which is the so-called oriented shipbuilding. And that is why the gamble LNG shipbuilding failed. The investment of LNG carrier is very huge and the payback period is very long such as 12 to 15 years. So the ship owner usually signs the contract of 20 to 25 years with the cargo owner. Shanghai LNG Corporation had ordered 5 LNG carriers in Hudong-Zhonghua Shipbuilding Corporation. And 2 of them are special ordered for Shanghai LNG program. The cost is about 200 million USD.

3.2.3 The Particularity of the LNG Commercial Contract

The commercial contract of LNG is the take or pay contract. The take or pay contracts mean the buyers must pay the money for the undelivered amount of cargo even the buyer can not receive total conventional amount of cargo. Nowadays, this term became looser than before and it allows the amount of delivery can be adjusted in a

range. Another characteristic of LNG commercial contract is that the contract length is very long. The contract between CNOOC and Petronas is 25 years long and the unit price is estimated between 5 to 6 dollars per Metric Million British Thermal Unit.

3.2.4 The Low Freight of LNG

The freight of LNG transportation equals the cost of the transportation plus a reasonable profit. The freight of LNG takes a large proportion of the value of the cargo. And usually the proportion is 20% to 25%. Nowadays, the internal rate of return of the LNG carrier is about 12% to 15%. If Chinese shipping companies undertake the carriage of imported LNG, the freight should be lower than the international standard. The reasons are as follows: first, the salary of Chinese seaman is lower than that from developed countries. Second, the administrative expenses of the shipping companies in China are much lower. Third, if the government implies the same preferential tax policy to the domestic companies, the cost will decrease further. So with the same IRR, our freight must lower than others.

3.3 The Risk of Shanghai LNG Import Program

3.3.1 The Risk of Performance of Contract

The risk of performance of contract means that the sellers can not supply the LNG according to the contract. Due to the trade of LNG are usually the long-term trade and the spot transaction only takes about 5% of the total trade volume, it is nearly impossible to buy the enough amount of LNG. If the supply of LNG stopped, the total program will be forced to stop. And this will make huge economical and social loss. Usually the main factors that make the performance of contract goes wrong are:

1. Gas field exhausted

This means the actual volume of exploitation is lower than the verified reserves of the gas field. And it will lead to a very serious result that the seller cannot supply enough LNG for the fixed years. In other words, there would be no gas to perform the contract.

2. Production facilities failure

This means the production facilities and the pipelines cannot work steady. This could be caused by many reasons such as violent typhoon or mechanical failure. And if the production facilities could not work well, the transportation of LNG will be delayed and the supply of gas to the final user may be affected.

3. Political and social risk

This means the unstable political and social situation of the export country may influence the production of LNG. For example if the staff of the Malaysia company is on strike, the production of LNG will stop and the supply of cargo will be delayed.

3.3.2 The Technical Risk

Most of the technical risks are faced by all kinds of ships. So there are matured technology and experience to prevent and manage. However, because the marine transportation of LNG has several special characteristics, it has not only the common risk but also some special technical risks.

1. The latent risk of LNG

Low temperature is the main danger of LNG, and LNG also has flammability just like other hydrocarbon. First, the extreme low temperature will do the permanent injury to human body. And it also can make the ordinary steel plates loose its ductility and break. Second, when the LNG leak in large quantity, it will form a pool and evaporate the flammable gas. If the gas is not lightened, it will form a flammable cloud above the water. And if this cloud is blown away to the other areas, it will create greater danger to the social.

2. The loading and discharging risk

The process of loading and discharging LNG is very special and strict. Usually it is: first, charging the inert gases into the pipelines so that there would not appear the flammable gases in it. Second, the water and water vapor in the cargo holds and pipelines must be eliminated totally so that the whole system would not be frozen. Third, before loading and discharging large amount of LNG, the pipelines and cargo holds must be cooled in advance. Or else, the pipelines and cargo holds may break by the huge heat stress. Forth, in the process of loading and discharging LNG, the inside pressure and the evaporation rate must be monitored all the time in order to avoid accidents. The process must be done from step to step and it must be very strict. If there is little carelessness, the result will be very serious.

3. The storage risk

When LNG is discharged and stored, the main risk will be the storage risk. And the main presentation of this risk is leakage of LNG. Once LNG leaks, a liquid bath will

form and it will transferred to vapor immediately. The vapor will form a cloud above the ground. If the cloud is lighted, a huge blazing fire will happen. The LNG storage tanks are heated by the fire for a long time and the strength of tanks will decrease with the increase of temperature. When the strength decreases to the yield limit of the tanks, the storage tanks will collapse suddenly and the LNG will gasification and initiation immediately. This will make the fire to huge explosion. This will make very terrible consequence.

4. Other technical risk

Other technical risk includes many factors such as unprofessional operation and the inherent defect of facilities.

3.3.3 The Market Risk

The market risk means the risk generated by the uncertainty of the market. Usually it is very hard to predict and precaution. The factors of the market risk are as follows:

1. Usage volume alteration

The LNG purchasing quantity may not balance with the amount of usage. When the purchasing quantity is larger than the amount of usage, the actual price of the gas will increase due to the take or pay contract. And on the contrary situation, the demand of users would not be satisfied and the cost of usage will increase. The both situation will influence the benefit of receiving station.

2. Price alteration risk

The price of LNG may not be cheaper than other clean energy in the future. At present, the price of LNG has an edge than other energy such as nuclear power, hydro power and LPG. But it is not sure that whether the price of LNG will become higher than others. And if so, the benefit of receiving station will decrease.

3. Future risk

Nowadays the world is suffering the economy crisis. So the demand of energy decreased and the competitions for LNG would not be so severity. At this time, the supply may be guaranteed. But if the economy get recovered and boom, the demand for energy must increase. And at that time, it may be not so easy to get enough amount of LNG.

4. Freight alteration risk

Freight is another important factor that influences the operation of LNG program. If the freight is too high, the final price of natural gas will exceed the holding capability of final user. And this will lead to the decrease of demand and the profit of LNG program.

3.4 The Suggestion for Shanghai LNG Program

3.4.1 The Precaution for the Contract and Market Risk

To any LNG program in the world, the main risk is that the buyer or seller can not hand over and take over the cargo normally. Any problem rise in either party will affect the

transportation section. If the risk is temporary such as the natural disaster or mechanical failure, the owner can reduce the loss to the lowest. When the risk is other such as social unstable, national relationship and war, the consequence will be very serious if it can not be solved on time. The worst situation will lead that the vessel stops operating even idle for a long time. This will make a huge loss to the owners. So at the early stage of the development, China must try to control the transportation right and ensure the stable supply of the LNG.

1. China control the transportation

First, it is good for the normal running of LNG program. If Chinese companies control the transportation, China will have the initiative and flexibility on the aspect of assuring the steady supply of gas. Once the supply of gas become difficult even break, our companies can command the vessels to other gas source region to carry LNG temporary so that we can assure the continuation of the supply. Otherwise, it will be difficult to transfer the vessel to solve the source crisis quickly. And it will make unnecessary great loss for our country.

Second, this can reduce the risk of carrying out the take or pay contract. After the formation of long term LNG trade contract, the trading volume should be decided by the annual demand volume. If the buyer can not take the fixed volume, he must pay the money of the fixed volume. That is the characteristic of take or pay contract. And when negotiate the contract, buyers usually wish that the annual trading volume can be more flexible so that they can avoid unnecessary loss. But sellers usually wish the contrary situation so that they can make the production of LNG more stable. Take an example, supposing the annual demand is 3 million tons. When negotiating the

contract, it will state "3±0.2 million tons a year" using the CIF or EX-SHIP term. But when using the FOB term, it can state "2.5±0.7 million tons a year". The reason of this is that the buyer can control the transportation and the transportation contract is negotiated by buyer. On the contrary, seller will give a larger basic volume to buyers when they can control the transportation. However, the basic volume is the base of take or pay. So the larger the basic volume is, the higher the risk is. As the above example, it can avoid the risk of paying for the freight of 500 thousand tons using FOB term.

Third, China should develop the LNG carrier fleets and shipbuilding industry. Our government can consult the way of other countries to give the political support. For example, our government can give the privilege on the aspect of loan and value added tax. So we can accelerate the development of our LNG fleet and shipbuilding industry.

2. Ensure the stable supply of LNG

There are two ways to ensure the stable supply of LNG. One is to control the upstream production and another is to buy gas from multiple sources. To control the production, our government should support the large state-owned enterprises such as Sinopec, Petro China and CNOOC to expand the overseas oil gas market. For instance, these companies can invest on the overseas gas fields so that they can take enough shares. To buy gas from multiple sources will ensure the diversification of the sources and divert the risks bring from the uncertainty.

3.4.2 The Precaution of Technical Risk

1. Improve the quality of seaman

The temperature of cargo carried by LNG carrier is - 162℃. And it is very danger to either human or machines. Due to the complex loading and discharging process and special demand of control and management, there must be a group of qualified seamen and technicians who know well about the safe operation and management. So establish a high quality seaman team is the key to assure the safe transportation of LNG carriers. There are three ways to improve the quality of seamen.

First, we can found the joint company. Chinese companies have rich experience of managing the LPG and crude oil carriers. But we have little experience about the management of LNG carrier. To prevent the risk and ensure the safety of the whole program, we should found the joint venture with the foreign companies which have the rich experience of LNG carrier management. This can use the mature management experience of foreign company to help our company to culture the managers and technicians. So our company can master the management technology of LNG carrier and lay the foundation for following programs.

Second, because LNG carrier is very dangerous and its control is very complex, it is very important to improve the responsibility, safety consciousness and seamanship of seamen. Many maritime accidents revealed that the occurrence of accidents is related to the weak safety consciousness and responsibility of seamen. And little fault on the sea may lead to great loss. And after assuring highly safety consciousness and responsibility, there is another thing to do that is to improve the seamanship of the crew. This is the most direct and effective method to prevent or decrease the happening of marine accidents. The reason is that the seaman is the direct manipulator of the vessel.

The most important representation of the seamanship is that the ability to find, analyze and solve problems under the complex situation. In other words, seamanship is the ability to use navigation skills and experience.

Third, fully understand the safety regulations about the operation and transportation of LNG. This will help to prevent the accidents. These regulations include:

(1) Do not allow smoking at any time on the deck or outside the cabin.
(2) Forbid any sparks, flame, welding or unsafe electronic equipments beside the LNG holds or pipelines.
(3) After the loading process finished, any doors and windows which lead to the storage area should remain closed. And make sure the air monitors have been installed.
(4) Make sure LNG would not contact with carbon steel. Eliminate it when there is a leakage.
(5) LNG should not contact with skin. Make sure wearing correct clothes when there is possibility to contact with LNG.
(6) Do not lock the stressful pipelines unless necessary.
(7) If the liquid leaks, block the scene and prevent the fire source. Repair it as fast as possible.
(8) Do not throw LNG into water unless necessary. Do not spray the water directly to the burning LNG.
(9) Do not allow entering into the LNG cargo holds unless the holds are inerting and ventilate sufficiently. And make sure there are enough oxygen content and taking safe equipment.

Fourth, the shipping companies should provide strict training to the crew. And build the system to track and feed back the information. So make sure the quality of seaman

is improved.

2. Tighten the safety management of LNG shipping company

One acknowledged statistical result reveals that 80% of marine accidents brought by the human factors. The liabilities of human factors are mainly on ashore and aboard the management. The company directly controls the macroscopic management of transportation system. Which employees to use, which route the vessels will operate and how to solve the danger situation are all depend on the company. So the company is an important section in the vessel safety management.

(1) There must be a safety department in the company. This department is responsible for the safety status of LNG carriers and training the crew. It must find and solve the problems of the vessels as early as possible. The company must be strict with the technical state and safety operation.
(2) Due to the LNG transportation is usually a 20 to 25 years long term contract and the characteristics of LNG programs, the transportation must be on time and reliable. But as a manager of LNG carrier, he must not only pursue the “correct time”. He should keep an eye on the technical states of the vessels.
(3) Deal the relationship between shipping company and seamen correctly. As the manager of the vessel, the shipping company is responsible for the management, supervision and usage of vessels and seamen. But the crew as the actual operators of the vessel, they are also responsible for the management, maintenance and operation of both vessel and cargoes. So the relationship between the crews and shipping company is very important. Many accidents revealed that the incongruous relationship directly affect the work of seamen especially senior officers. This will also affect the safety navigation of the vessels. This demands

that the shipping company need not only to regulate the behaviors of crews but also enforce their cohesion. This demands the decision makers :

(a) Draft and perfect the regulations and apply the scientific quality management system.

(b) Rational deployment the crews so that to reduce the fatigue factors and assure their normal biorhythm.

(c) Respect the opinions of crews especially the senior officers. Renew the equipment and assure the supply of material. And never encourage the captain to navigate the vessel eyeless.

3. Strengthen the safety management of ports

Due to the particularity of the cargo and operation of LNG ship, the vessel must be checked strictly before starting the loading and discharging process. Many countries do not allow the LNG carriers enter the port at night. And there must be ships beside the LNG carriers when she entering the port. Attentions and requirements are different from country to country. And after arrival, both the LNG carrier and terminal should check strictly according to the “Terminal Safety Check List”. Before loading and discharging, all the safety, work system and emergency contact line should be tested well. When loading and discharging, all the other activities such as replenishment, oiling and repair are not allowed. If there is necessary, it must be permitted by the port authority.

Chapter 4 The Risk Evaluation Model for LNG Program

Although the LNG program has several risks as the chapter 3 stated, usually these risks were researched and demonstrated. Most LNG programs are working well and there were no big technical or commercial problems happened. Also there was no situation appeared that LNG sellers stopped supply LNG. And the operation of LNG carriers is also very safe. In the history of its operation, there is no serious accident happened. So we can get the conclusion that the LNG programs are very reliable. But we must nip the accidents in the bud. Especially Chinese companies do not have many experiences on the management of LNG programs. So we must analysis the risk that LNG program will face. The most efficient method is to use a variety of mathematical methods to do the general analysis. And then we can apply the countermeasure to deal with these risks.

4.1 The Selection of the Methodology

The many factors that can influence the risk of LNG program are uncertain and fuzzy such as good, bad, high and low. These can not be measured by the certain quantity. So when analysis the risk of LNG program, we can not just select the quantitative indexes

and abandon many fuzzy but important indexes.

The Fuzzy Comprehensive Evaluation is such a method that it can analysis the thing which is affected by many factors. It not only has the strict quantitative analyses but also has the qualitative description of those fuzzy factors. This method is suitable for subjective indicators and objective indicators. There are three characteristics of the Fuzzy Comprehensive Evaluation: first, it does not only rely on a particular index or absolute index. It uses the comparative method so that it can avoid the result deviation caused by the irrational indexes selected. Second, the importance degree is embodied by the weight number. But this method allows some deviations of the weight number and this would not change the final results. Third, the selection of arithmetic operators and the establishment of membership function build the connections among those non-quantitative indexes.

So after consider the fuzziness of the indexes which are used to evaluate the risks that the LNG programs will face, the fuzzy comprehensive evaluation is considered to be the best method to analysis the risks.

4.2 Fuzzy Comprehensive Evaluation

4.2.1 The Procedure of Fuzzy Comprehensive Evaluation

Multi-level Fuzzy Comprehensive Evaluation mainly uses the evaluation result of single factor related to the analysis object to build the judgment matrix. And then it will do the fuzzy mapping with the weight factors which determine the importance degree of all factors. After that, we can get the final result. The advantage of this method is: the mathematical model is simple and the procedure of data processing is

clear and easy to change and control.

Usually, the procedures of Fuzzy Comprehensive Evaluation include:

First, divide the factor sets into several subsets according to their properties.

$$U = \bigcup_{i=1}^{s} u_i$$

We set subset $u_i = \{u_{i1}, u_{i2}, \ldots u_{in}\}$, i= 1, 2, …, s is the factor subset of U.

Second, do the single stage fuzzy comprehensive evaluation to each factor subsets u_i.

Suppose the evaluation set is V= $\{v_1, v_2, \ldots, v_m\}$

The evaluation set includes all kinds of possible results of the evaluation. Each factor (v_1, v_2….) represent the results of every possibility. The fundamental purpose of fuzzy comprehensive evaluation is to select the best result from the evaluation set after considering all the effect factors.

The fuzzy weight vector of all factors in u_i is:

$$A_i = (a_{i1}, a_{i2}, \ldots, a_{ip})$$

$$\sum_{r=1}^{r=p_i} a_{ir} = 1$$

A is one of the subsets of U and it reflects the important degree of each factor. So it is called weight.

The single factor evaluation result of u_i is R_i (P_i line, m row), the single stage evaluation model is:

$$A_i \circ R_i = (b_{i1}, b_{i2}, \ldots, b_{im}) = B_i (i = 1, 2, p_i)$$

In this formula, "$\circ$" means fuzzy operator. Different definitions of this operator corresponds different models. In the generalized fuzzy operation, each factor in B:

$$b_j = (a_1 * r_{1j}) \overset{+}{*} (a_2 * r_{2j}) \overset{+}{*} \ldots \overset{+}{*} (a_m * r_{mj}) (j = 1, 2, \ldots n)$$

This is called model M($*, \overset{+}{*}$) for short. "*" means generalized fuzzy "and" operation "$\overset{+}{*}$" means generalized fuzzy "or" operation. b_j means the degree of membership of v_j to the fuzzy evaluation sets B.

Third, we regard u_i as a comprehensive factor. And if we suppose B_i as the results of its single factor evaluation, we can get the matrix of degree of membership.

$$R = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_s \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & b_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ b_{s1} & b_{s2} & \cdots & b_{sm} \end{bmatrix}$$

We set the fuzzy weight vector of u_i (i = 1, 2, …, s) is:

$$A = (a_1, a_2, \ldots, a_s)$$

While secondary fuzzy evaluation model is:

$$B = A \circ R = (b_1, b_2, \ldots, b_m)$$

If $b_r = \max_{1 \le j \le m} \{b_j\}$, the evaluate object is belong to the r level according to the maximum membership principle.

From the figure 4.1 we can find the process of the fuzzy comprehensive evaluation. First it does the fuzzy evaluation to those basic indexes classified by their property. And then combine the previous results to form the evaluate matrix of the indexes of

upper level. Analogizing like this, we will get the final results.

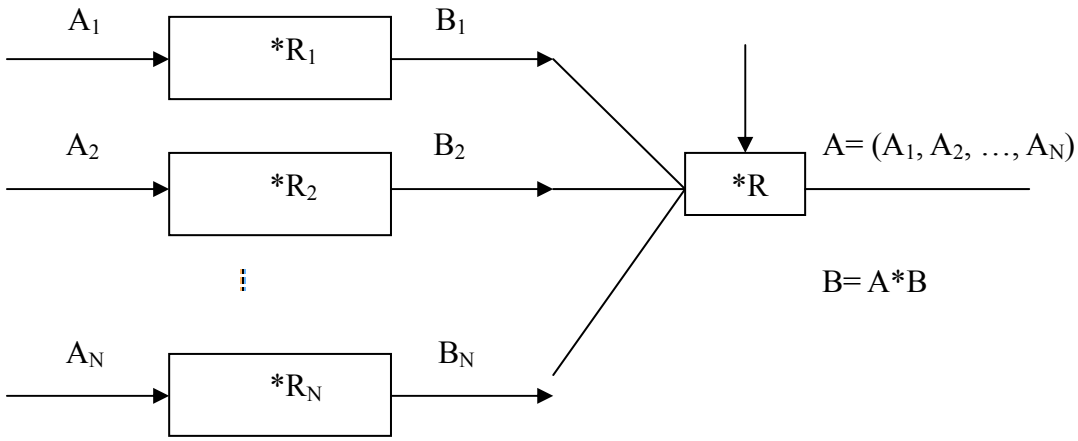


Figure 4.1 sketch map of lower model

Source: Drawn on my own

4.2.2 The Selection of the Mathematic Model

The formula $B = A \circ R$ will transfer the operation fuzzy vectors into the grade fuzzy vectors though the fuzzy evaluation matrix R. And it has different calculation modes which will lead to different mathematic models. Usually there are five models to be selected. (See table 4.1).

Table 4.1 five commonly used fuzzy math model

Model type	Code name	Meaning of operator

Model I	M ($\wedge$,$\vee$)	$a \vee b = \max(a,b)$	$a \wedge b = \min(a,b)$
Model II	M ($\cdot$,$\vee$)	$a \vee b = \max(a,b)$	$a \cdot b = a \cdot b$
Model III	M ($\cdot$,$\oplus$)	$a \oplus b = \min(a+b,1)$	$a \cdot b = a \cdot b$
Model IV	M ($\wedge$,$\oplus$)	$a \oplus b = \min(a+b,1)$	$a \wedge b = \min(a,b)$
Model V	M ($\cdot$,+)	$a+b=a+b$	$a \cdot b = a \cdot b$

Source: Drawn on my own

Among these five models, they get their results under the situation that there exists some particular restricts and need to take the limits. The first four models will lose many useful messages, but Model V will keep the entire message. This model can be used when we need to consider the effect of each factor. So according to the demand of actual problems, Model V is selected. In this Model, M ($\cdot$,+) use $\cdot$ and + instead of $*$ and $\overset{+}{*}$. So $b_j = \sum_{j=1}^{m} a_i r_{ij} \ (j = 1,2,\dots,n)$.

4.3 The Establishment of the Index System of LNG Program Risk Evaluation

4.3.1 The Principle of the Establishment of Indexes

1. Purposiveness and comprehensiveness

The index system should be the objective description of the characteristics, structure and component of the target of evaluation. And also it should be the represent of the aim of evaluation. The principle of purposiveness is the base of the index system and

also an important criterion to test whether the system is effective. The principle of comprehensiveness demands the risk evaluation should not miss the main indexes. The LNG programs face many complex risks and it is hard to reflect the actual situation of evaluate object with single index. So we must consider all the possible factors and set relevant indexes to reflect the effects on the object.

2. Scientificity and practicability

The scientificity of index system is the base of the correct results. This principle demands that indexes should reflect the characteristics of the objects and the definition of indexes should be correct. Also it demands the structure of indexes must be rational, independent and comprehensive. The principle of practicability means that possibility of realization should be considered when designs the index system. The indexes should be easy to understand and accept to users. And it should use matured and acknowledged indexes for the application and comparison of the results. This principle is the base to ensure the quality of evaluation.

3. Logicality

There should not be strong relevance among the indexes. The indexes should not contain too many information to avoid the overlap of the indexes. But if the indexes are irrelevant, they would not be an organic whole. So the indexes should be relevant.

4.3.2 The Selection and Quantification of Index

1. The filtration of index

In the practical application, there is a general principle that is use the least indexes to describe the nature of the problems. Due to indexes include some less important one; we need to remove them according to the principle of rationality.

The specific technique of filtration is weight judgment method. This method is based on the value of weight number. To remove some small weigh number indexes will simplify the problem so that it would not make the user chaos and fault. The specific steps are as follows:

Suppose the evaluation index system $F = \{f_1, f_2, \dots, f_n\}$, and the relevant weight number set is $\lambda = \{\lambda_1, \lambda_2, \dots, \lambda_n\}$ $\lambda_i \in [0,1] (i = 1,2, \dots, n)$. And if $\lambda_1 \leq \lambda_k$, the index $f_l$shall be kept. And if $\lambda_1 > \lambda_k$, the index f_l shall be removed. λ_k is option weight which depends on the degree of complex of the object. The more the factors are, the less the option weight number is. Usually we suppose λ_k is 0.1.

2. The quantification of index

The indexes can be divided into two kinds: one is quantitative one such as the economy indexes. We can calculate the value of these according to the statistical results. Another is qualitative one such as the technical level and market competition. These indexes are hard to quantitative and it is a big problem in the evaluation. The qualitative indexes can be classified by level language. According to measure principle of psychology, we set the level of index is:

$V = \{v_1, v_2, \dots, v_m\}$

Usually we suppose $m = 5 \pm 2$, we classify the qualitative index as:

$$V = \{highest, higher, normal, lower, lowest\}$$

$$V_2 = \{very\ high, high, little\ high, normal, little\ low, low, very\ low\}$$

Different level will get different value of scale mark so that we can get the value of scale mark of index. However, the qualitative index usually is fuzzy and it is hard to make sure its exact level. We can only get the probability of which level the index will belong. In the fuzzy mathematic, this is to get the degree of membership of the index on the evaluation level. The degree of all indexes is called membership function. There are main methods to confirm the function. One is fuzzy statistical method. First the group of experts will decide the level of the index. And then count the frequency of each level. The degree of membership is the ratio that each frequency compares the total number of experts. Another method is to use the graph of function. Generally we suppose the membership function is linear function. Then we build the graph which horizontal axis is the value of index and vertical axis is membership. If there are m levels, we set m fold lines. These represent the member function of each level.

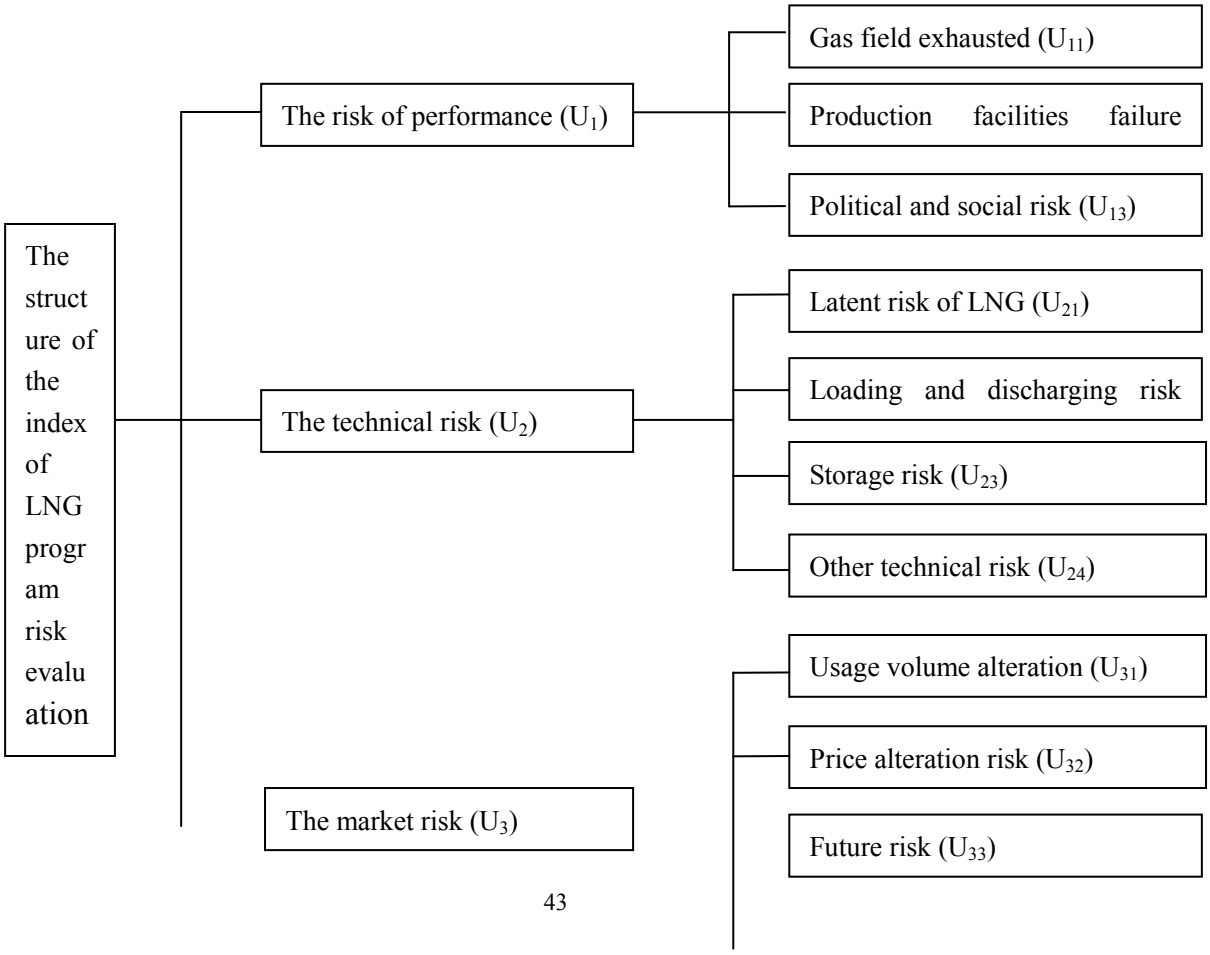
4.3.3 The Structure of Indexes

Though the analysis of the third chapter, we can build the system of LNG program risk comprehensive analysis according to the above principles.

The risk of performance of contract (U_1): gas field exhausted (U_{11}), the production facilities failure (U_{12}), and political and social risk (U_{13}).

The technical risk (U_2): the latent risk of LNG (U_{21}), the loading and discharging risk (U_{22}), the storage risk (U_{23}) and other technical risks (U_{24}).

The market risk (U_3): the usage volume alteration (U_{31}), the price alteration risk (U_{32}), the future risk (U_{33}), and freight alteration risk (U_{34}).



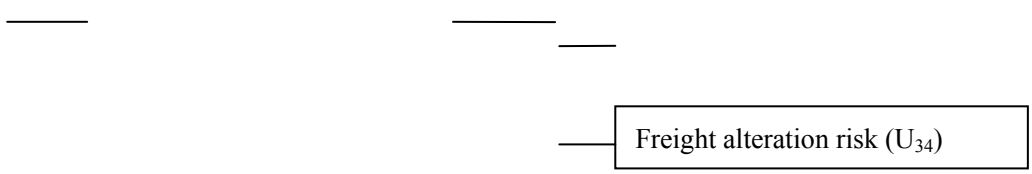


Figure 4.2 the risk evaluation index system

Source: Drawn on my own

4.4 The Method for Deciding Weight

The weight represents the relative importance degree of each index. In the multi-index evaluation, how to allocate the weight is the key to quantizing the evaluation. The weight embodies the leading intention and values of evaluator. So to some extent, the weight has much more effect on the evaluation results. It does not only affect the evaluation result of one index but others. Due to the sum of weight of all indexes is the same, the weight of other indexes will decrease when the weight of one index increase. This may lead to the change of the important degree of each index.

Nowadays, there are several methods to decide the weight. They are divided into two kinds which are subjective empowerment method and objective empowerment method. Dephi method, Analytic Hierarchy Process and Frequencies Analysis are belonging to the subjective method. Principal Component Analysis and Entropy Method are belonging to the objective method. The SEM mainly relies on judgment of experts and then uses different methods to empower the index.

LNG program is a very complex system. There are so many factors that affect its operating risks. What is more, most of them can not be represented by the function though quantitative method. Analyzing these factors must rely on the experience of experts. So we select Dephi method to decide the weight of the indexes.

Chapter 5 The Quantitative Analysis of Risk for Shanghai LNG Program

5.1 The Factor Set and Evaluation Set

5.1.1 The Factor Set

The fix of the factor sets is the key whether the fuzzy evaluation can be rational. The factor sets of LNG risk evaluation are:

$$U = \{U_1, U_2, U_3\}$$

In this set, there are three sub sets:

$$U_1 = \{U_{11}, U_{12}, U_{13}\}$$

$$U_2 = \{U_{21}, U_{22}, U_{23}, U_{24}\}$$

$$U_3 = \{U_{31}, U_{32}, U_{33}, U_{34}\}$$

5.1.2 The Evaluation Set

The purpose of fuzzy comprehensive evaluation is to get the optimal result from the evaluation set V though considering all factors. After consult the usual level division method in the research of experts from home and abroad, this article will use the evaluation set of five levels. Define the set as:

$$V = \{V_1, V_2, V_3, V_4, V_5\}$$

And V_1, V2, V3, V4, and V_5 means lowest, lower, normal, higher, and highest risk. According to the standard of each index, table 5.1 show the level division of each level.

Table 5.l appraisal standard of evaluation index and risk hierarchy

		V_1	V_2	V_3	V_4	V_5
U_1	U_{11}	The output of the gas field is very stable.	The output of the gas field is seldom unstable.	The output of the gas field is occasionally unstable.	The output of the gas field is often unstable.	The output of the gas field is always unstable.
	U_{12}	The facilities always work well.	The facilities seldom break down.	The facilities occasionally break down.	The facilities often break down.	The facilities always break down.
	U_{13}	The political situation is	The political situation is	The political situation is	The political situation is	The political situation is

		very stable.	seldom unstable.	occasionally unstable.	often unstable.	always unstable.
U_2	U_{21}	The latent danger of LNG never poses a threat to the program.	The latent danger of LNG seldom poses a threat to the program.	The latent danger of LNG occasionally poses a threat to the program.	The latent danger of LNG often poses a threat to the program.	The latent danger of LNG always poses a threat to the program.
	U_{22}	The operation processing of LNG never poses a threat to the program.	The operation processing of LNG seldom poses a threat to the program.	The operation processing of LNG occasionally poses a threat to the program.	The operation processing of LNG often poses a threat to the program.	The operation processing of LNG always poses a threat to the program.
	U_{23}	The storage risk never poses a threat to the program.	The storage risk seldom poses a threat to the program.	The storage risk occasionally poses a threat to the program.	The storage risk often poses a threat to the program.	The storage risk always poses a threat to the program.
	U_{24}	The other technical risk never poses a threat to the program.	The other technical risk seldom poses a threat to the program.	The other technical risk occasionally poses a threat to the program.	The other technical risk often poses a threat to the program.	The other technical risk always poses a threat to the program.
U_3	U_{31}	The usage volume is always balanced with the fixed volume.	The usage volume is seldom unbalanced with the fixed volume.	The usage volume is occasionally unbalanced with the fixed volume.	The usage volume is often unbalanced with the fixed volume.	The usage volume is always unbalanced with the fixed volume.
	U_{32}	The price of LNG will be much cheaper than other energy in the future.	The price of LNG will be little cheaper than other energy in the future.	The price of LNG will be the same with other energy in the future.	The price of LNG will be little more expensive than other energy in the future.	The price of LNG will be much more expensive than other energy in the future.
	U_{33}	The competition for LNG will be always	The competition for LNG will be seldom strong	The competition for LNG will be occasionally	The competition for LNG will be often strong in	The competition for LNG will be always strong

		weak in the future.	in the future.	strong in the future.	the future.	in the future.
	U_{34}	The freight of LNG transportation will be always cheap and stable.	The freight of LNG transportation will be seldom high and unstable.	The freight of LNG transportation will be occasionally high and unstable.	The freight of LNG transportation will be often high and unstable.	The freight of LNG transportation will be always high and unstable.

Source: Drawn on my own

5.2 The Fix of Weight though Delphi Method

First, sending the questionnaire to the experts or experienced personal. Then they will decide the weight for each index based on their own judgment to the important degree. After regain these questionnaire, I will do the data processing and examine the degree of intensity, dispersion and coordination of the expert opinions. Finally, we can get the weight vector of each index.

$$\bar{e_{ij}} = \frac{1}{s}\sum_{j=1}^{s} e_{ij}\ (i = 1,2, \dots, n)$$

$\bar{e_{ij}}$ is the mean of the weight of the i_{th} index.

e_{ij} is the weight that the j_{th} expert deicide for i_{th} index.

S is the number of experts.

After the normalization processing, we get

$$e = \left(\frac{\bar{e_1}}{\sum_{i=1}^{n}\bar{e_i}}, \frac{\bar{e_2}}{\sum_{i=1}^{n}\bar{e_i}}, \dots, \frac{\bar{e_n}}{\sum_{i=1}^{n}\bar{e_i}}\right)$$

So, after calculation, we get the results:

The weight of one grade index: $W = (0.33, 0.37, 0.3)$

The weight of second grade index: $W_1 = (0.3, 0.39, 0.31)$

$$W_2 = (0.26, 0.26, 0.24, 0.24)$$

$$W_3 = (0.25, 0.26, 0.25, 0.24)$$

5.3 The Establishment of the Membership Degree Matrix

In the theory of fuzzy mathematic, the methods to fix the membership function or degree are: fuzzy statistical method, rationalistic method and fuzzy distribution method. What is more, there is a common used method which is called experts investigating. The process of it is: first, make the expert investigating table and send them to the experts. There states the risk level for each index on the table. The experts will select the risk level based on their own experience. Second, recall these tables and collect the data. Then we can get the frequency of each index to the level. Finally, after the normalization process, we will get the member degree of each index. So we can get the single factor judgment matrix. This method is a bit subjective but it can reflect the accumulation of experience.

So based on the advantage of expert investigating, we use the data from the questionnaire to evaluate each index. And we get the fuzzy evaluation matrix:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_m \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

In the above formula, $R_i = (r_{ij}), r_{ij} (i = 1,2, \dots, m; j = 1,2, \dots, n)$ means the membership degree of the i index to the j remark in the evaluation set. It use the

membership degree to describe the fuzzy relationship between the evaluation factor and level. $r_{ij} = d_{ij}/d$, d_{ij} means the number of experts that give the j remark to the i index. d means the total number of experts.

So the matrix is:

$$R_1 = \begin{bmatrix} 0 & 0.08 & 0.42 & 0.33 & 0.17 \\ 0 & 0 & 0.08 & 0.5 & 0.42 \\ 0 & 0.08 & 0.42 & 0.33 & 0.17 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0.08 & 0.25 & 0.33 & 0.33 \\ 0 & 0.08 & 0.25 & 0.58 & 0.08 \\ 0 & 0.33 & 0.42 & 0 & 0.25 \\ 0 & 0.08 & 0.33 & 0.42 & 0.08 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0.17 & 0.25 & 0.33 & 0.25 \\ 0 & 0.17 & 0.42 & 0.33 & 0.08 \\ 0 & 0.25 & 0.5 & 0.17 & 0.08 \\ 0 & 0.33 & 0.33 & 0.17 & 0.17 \end{bmatrix}$$

5.4 The Analysis of the Results

The risk of performance of contract is divided into 3 aspects: gas field exhausted the production facilities failure and political risk. The comprehensive weight vectors of those three factors are:

$$A_1 = W_1 = (0.3, 0.39, 0.31)$$

And the index membership matrix is:

$$R_1 = \begin{bmatrix} 0 & 0.08 & 0.42 & 0.33 & 0.17 \\ 0 & 0 & 0.08 & 0.5 & 0.42 \\ 0 & 0.08 & 0.42 & 0.33 & 0.17 \end{bmatrix}$$

The fuzzy evaluation result vector is:

$$B_1 = A_1 \cdot R_1 = (0, 0.05, 0.29, 0.39, 0.27)$$

From A_1 we can get the proportion that these three factors take. The production facilities failure takes 39% of the total risks from sellers. It is the most important factors to affect the risks.

And from the first grade fuzzy evaluation result $\mathbf{B_1}$, we can get the conclusion that: the membership degree of lowest risk is 0%, lower risk is 5%, normal risk is 29%, higher risk is 39% and highest risk is 27%. So the risk of performance of contract will always exist and the possibility of appearance will be higher.

With the same method we can get the fuzzy evaluation result vector of the technical risk is:

$$\mathbf{A_2} = \mathrm{W_2} = (0.26, 0.26, 0.24, 0.24)$$

$$\mathbf{R_2} = \begin{bmatrix} 0 & 0.08 & 0.25 & 0.33 & 0.33 \\ 0 & 0.08 & 0.25 & 0.58 & 0.08 \\ 0 & 0.33 & 0.42 & 0 & 0.25 \\ 0 & 0.08 & 0.33 & 0.42 & 0.08 \end{bmatrix}$$

$$\mathbf{A_2} \cdot \mathbf{R_2} = (0, 0.14, 0.31, 0.34, 0.19)$$

After the normalization, $\mathbf{B_2} = (0, 0.14, 0.32, 0.35, 0.19)$.

From $\mathbf{A_2}$ we can get the portion of four secondary grade indexes. The latent danger of LNG takes 26% of total risk. And loading and discharging risk is 26%, storage risk takes 24% and the same percentage of other technical risk.

And from the first grade fuzzy evaluation result $\mathbf{B_2}$, we can get the conclusion that: the membership degree of lowest risk is 0%, lower risk is 14%, normal risk is 32%, higher risk is 35% and highest risk is 19%. So the technical risk will always exist and the

possibility of appearance will be just higher.

The fuzzy evaluation result vector of the market risk is:

$$A_3 = W_3 = (0.25, 0.26, 0.25, 0.24)$$

$$R_3 = \begin{bmatrix} 0 & 0.17 & 0.25 & 0.33 & 0.25 \\ 0 & 0.17 & 0.42 & 0.33 & 0.08 \\ 0 & 0.25 & 0.5 & 0.17 & 0.08 \\ 0 & 0.33 & 0.33 & 0.17 & 0.17 \end{bmatrix}$$

$$B_3 = A_3 \cdot R_3 = (0, 0.23, 0.38, 0.25, 0.14)$$

From A_3 we can get the portion of four secondary grade indexes. The usage volume alternation takes 25% of total risk. And price alteration risk is 26%, future risk takes 25% and freight alteration risk is 24%.

And from the first grade fuzzy evaluation result B_3, we can get the conclusion that: the membership degree of lowest risk is 0%, lower risk is 23%, normal risk is 38%, higher risk is 25% and highest risk is 14%. So the market risk will always exist and the possibility of appearance will be just normal.

After get the results of the above three sub sets, we can combine B_1, B_2, and B_3 to get the membership matrix R of secondary fuzzy evaluation:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} 0 & 0.05 & 0.29 & 0.39 & 0.27 \\ 0 & 0.14 & 0.32 & 0.35 & 0.19 \\ 0 & 0.23 & 0.38 & 0.25 & 0.14 \end{bmatrix}$$

The comprehensive vector weight of the total risk of Shanghai LNG program is:

$$A = W = (0.33, 0.37, 0.3)$$

So the result of secondary fuzzy comprehensive evaluation is:

$$B = A \cdot R = (0, 0.14, 0.33, 0.33, 0.20)$$

From A we can get the portion of each risk. The risk from seller takes 33% of total risk. And transportation risk is 37% and risk from buyer is 30%. The portions of three risks take are not very different. Especially the risk of market and performing the contract is nearly the same. So we can conclude that these two have the same effect on the LNG program.

And from the first grade fuzzy evaluation result B_3, we can get the conclusion that: the membership degree of lowest risk is 0%, lower risk is 14%, normal risk is 33%, higher risk is 33% and highest risk is 20%. So from these membership degrees we can get the conclusion that the risk of Shanghai LNG program will always exist but the possibility of appearance will be normal or higher.

So the total risk of Shanghai LNG program is:

$$1 \times 0 + 2 \times 0.14 + 3 \times 0.32 + 4 \times 0.34 + 5 \times 0.2 = 3.6$$

According to the setting of level, 3.06 are belonging to the normal risk. So the possibility of risk is normal.

Chapter 6 Conclusion

Now energy is the lifeblood of the development of world economy. And with the decrease of the output of the traditional energy such as oil and coal, more and more countries begin to develop the new energy. And under this situation, LNG receives scrutiny for its cleanness and high efficiency. In recent years, Chinese government put more and more emphasizes on the development of LNG industry. And the number of import programs increased very fast. Nowadays small-scale LNG plants and LNG satellite gasification stations also get sudden rise. The consequence will be very serious if there is something wrong with the LNG programs. So it is very necessary to do the risk evaluation for LNG program.

This article analysis the risk factors that affect the operation of Shanghai LNG program based on the risk management theory and risk evaluation theory. Then the evaluation indexes system is established in order to do the next calculation. After that, the author use Dephi method to calculate the weight of each index. Finally we get the results though put all the data into the fuzzy comprehensive evaluation model.

So the article gets the conclusions as follows:

1. The risk that Shanghai LNG program will face is decided by many factors. And the author sum up that the risks are from three aspects: seller, transportation and buyer.

2. Though establishing the scientific and completed risk evaluation index system, it can calculation the risk level of the LNG program by using the fuzzy comprehensive evaluation. So it can help to avoid some risk or lower the loss.

3. From the evaluation result, we can find that the risk from transportation is the main risk that the LNG program will face. And the second is the risk from seller. Then it is the risk from buyer.

4. To reduce the transportation risk, Shanghai LNG program should found the joint shipping company with the foreign companies who have the lots experience of managing LNG carriers. So that we can master the technology of managing LNG ships as quickly as possible. Also our port authorities should learn the safety code of foreign ports so that to ensure the LNG vessels safety when they are in the ports.

5. To reduce the risk from seller, we should invest into the LNG gas fields so that our company can control the production. Besides, it is very necessary to import LNG from multi gas sources in order to separate the risks.

6. To reduce the risk from buyer, our company should enhance the safety management of itself. So the receiving or other facilities would not break down so frequency. And also central and local government should give political support to the LNG import company.

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