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Research on the development of fleet for carrying imported crude oil in China

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RESEARCH ON THE DEVELOPMENT OF FLEET FOR CARRYING IMPORTED CRUDE OIL IN CHINA

By

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China

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Research on the Development of Fleet for Carrying Imported Crude Oil in China**

Degree: **MSc**

With the rapid development of the economy of China, the demand for crude oil is becoming larger and larger. However, comparing with the fast growth rate of consumption, the crude oil produced by China itself is difficult to meet the demand. To lessen the gap between production and consumption, importing crude oil from other areas of the world is imperative under the situation. To transport imported crude oil to China, a large fleet is needed. Nowadays, Chinese national fleet only can afford to carry less than 10% of the waterway imported crude oil. But it is safe to carry at least 50% of oil by national fleet to guarantee the safety of energy sources. So many Chinese shipping companies are starting to expand the scale of their tanker fleet to be able to carry more percentage of the imported crude oil. So it is necessary to research on the development of the fleet carrying imported crude oil.

There are 4 main parts in this thesis. First, I will analyze the crude oil market of the world as well as China. The production and consumption of crude oil of China will be introduced here. By comparing the data of supply and demand, it can be found that the large amount of imported crude oil is inevitable. Secondly, according to historical statistics, the prediction of the amount of imported crude oil of our country is conducted using quantitative method and adjusted by qualitative analysis. Thirdly, the problem of fleet deployment planning is transformed into a linear programming problem and the fleet deployment model is established to compute the

optimal solution of the fleet development. Lastly, some problems that we may encounter during the development of fleet are discussed.

KEYWORDS: Fleet Deployment, Imported Crude Oil, China, Transportation

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LIST OF ABBREVIATIONS

OPEC	Organization of Petroleum Exporting Countries
OECD	Organization for Economic Cooperation and Development
BP	British Petroleum
EME	Emerging Market Economy
EU	European Union
USA	United States of America
GDP	Gross Domestic Product
SPSS	Statistical Product and Service Solutions
CPC	Communist Party of China
SINOPEC	China Petroleum & Chemical Corporation
CNPC	China National Petroleum Corporation
CNOOC	China National Offshore Oil Corporation
IEA	International Energy Agency
VLCC	Very Large Crude Carrier
ISM	International Security Management
COSCO	China Ocean Shipping (Group) Company
COSCODL	Dalian Ocean Shipping Company
CSC	China Changjiang National Shipping (Group) Corporation
LPG	Liquefied Petroleum Gas
DWT	Deadweight Tonnage
HOSCO	Hebei Ocean Shipping Co., Ltd
VLOC	Very Large Ore Carrier
USD	U.S. Dollar
IMO	International Maritime Organization

1. INTRODUCTION

After the open and reform of China, with the rapid development of the economy, the demand for oil, especially crude oil, is becoming increasingly larger. From 1990 on, the crude oil consumption of China was growing at an average speed of 7%. In the year 2003, China became the second largest crude oil consumer in the world. However, comparing with the fast growth rate of consumption, the crude oil produced by China itself is difficult to take more percentage for some technological reasons. Also, the exhaustion of the old generation of China's main oil field such as Da-qing and Sheng-li Oil Field is another reason for the shortage of production.

As we all known, crude oil is an important strategic resource as well as the main energy we use today. It is indispensable to the growth of national economy. To lessen the gap between production and consumption, importing crude oil from other areas of the world is imperative under the situation. Most of the crude oil imported to China is transported by water. So a large fleet is needed to fulfill the requirement. Nowadays, Chinese national fleet only can afford to carry less than 10% of the waterway imported crude oil. But it is safe to carry at least 50% of oil by national fleet to guarantee the security of energy sources. (Chen Guo-xiong and Wei Chun-ling, 2005, pp.16-17) So many Chinese shipping companies are starting to expand the scale of their tanker fleet to be able to carry more percentage of the imported crude oil. So it is necessary to research on the development of the fleet carrying imported crude oil.

Chapter 1 is a brief introduction of the paper, including the literature review.

In chapter 2, I will analyze the crude oil market of the world as well as China. The production and consumption of crude oil of China will be introduced here. By comparing the data of supply and demand, it can be found that the large amount of imported crude oil is inevitable.

In chapter 3, according to historical statistics, the prediction of the amount of imported crude oil of our country is conducted using quantitative method and adjusted by qualitative analysis.

In chapter 4, the status quo of the existing national fleet for transporting imported crude oil is introduced. And the main routes and loading/discharging ports for crude oil transportation is presented. According to the analysis, the limitations of the existing fleet are found at the end.

In chapter 5, the problem of fleet deployment planning is transformed into a linear programming problem and the fleet deployment model is established to compute the optimal solution of the fleet development. The sensitivity analysis is then applied.

In chapter 6, some problems that we may encounter during the development of fleet are discussed.

And chapter 7 is the conclusion.

1.1. Literature Review

Presently, there are 3 main planning methods used in domestic and overseas shipping companies for fleet deployment problems. They are: the method of traditional scheme, the method of vessel operation chart and the method of mathematic programming.

The first two methods require abundant experience and subjective judgment. And they are not able to solve a problem of fleet deployment planning in which there are several sea routes and several types of vessels. These two methods are applied widely in developing countries, including China.

The method of mathematic programming requires people to transform a real problem into a mathematic model, and compute the optimal solution by special algorithm. As the workload is substantive, computers are usually used to support the computing and accelerate the speed. This method is widely used in developed countries. With the popularization of computer in developing countries, this method becomes more and more prevalent in China to solve problem of fleet deployment planning.

Since the environment of shipping is complex and inconstant, and there are so many factors of influence to affect the future shipping market, it is difficult to accurately work out an optimal solution for a real fleet deployment case empirically. It is not an easy task even when using computer technology and mathematical model. To make the fleet deployment more scientific and reasonable, there are many specialists, scholars and researchers keep studying this problem.

John L. Everett and some scholars made a systematic research on the structure of fleet for carrying large amount of bulk cargo in America. They considered comprehensively about the factors of influence in the facet of management and

operation. They proved that the cost and structure of fleet have great influence on the selection of ports, but they have less influence on the amount of cargo to transport. This model can give instruction to the shipping companies for the decision of investment on ships. But it can only be applied on the problem of fleet deployment planning of a new-build fleet, not for the problem of fleet deployment planning of an existing fleet.

The Netherlandish scholars Ir. M. A. Wijismuller and J. G. B. Bermee made a research on the problem of vessel replacement and investment optimization of an existing fleet according to the prediction of the future market and they established a model. The objective of this model was to maximize the total present value (profits from operation + incomes from financial investment and loan – income taxes) of each year in the planned time horizon. This model definitely reveals the dynamic relationship among vessel replacement, investment and time. The main factors that affect the planning of fleet deployment such as problem of loan and problem of lease were fully considered in this model. At the same time, this model is too complicatedly formed and it doesn't consider the turnover forecast and ship deployment under the multi-routes situation.

Professor Xie Xin-lian set up a model of fleet deployment planning in the late 80s of the 20th century. Certain routes and their certain turnover are the pre-requisites to this model. The objective is to minimize the costs including operation cost and acquisition cost (buying and building). Professor Xie comprehensively considered the factors such as the capability of the existing vessels, the profitability and economic status of the vessels, the idle time of the vessels, the retirement of old vessels and the new building or buying of vessels. He unitized the routing plan of the fleet with the ship building plan. Zhang Lu-feng in Shanghai Jiao-tong

University also did research on this problem. He first selected the most appropriate types of vessels for our country, and based on this he used the model for single route operation to transform the problem of fleet deployment planning to a linear programming problem. Chen Jun, a graduate student in Shanghai Maritime University researched this problem too. He used linear programming and set the objective as maximizing the net income of the last year in the planned time horizon. He considered the factor of loan, tax and freight rate in the market.

S. C. Cho and A. N. Perakis cooperatively designed a linear programming and integer programming model for the routing problem of a fleet in 1994. Their objective is to optimize the economic benefits of each vessel deployed in each route. In 1997, S. C. Cho and A. N. Perakis cooperate for another time and pointed out an ideal method to solve the problem of fleet deployment planning and routing. They analyzed an example, but didn't give the process of computing.

B. J. Powell and A. N. Perakis summarized the former researches on fleet deployment planning and raised a new opinion. They thought that all the factors of influence should be considered comprehensively, and they believed that the model which mixed linear programming and integer programming is applicable to the problem of fleet deployment planning. However, the new model they designed only stay in the theoretical stage, it needs to be further studied to be applied practically.

T. A. J. Nicholson and R. D. Pullen used dynamic programming algorithm to solve a 10-year deployment problem of a fleet whose scale is diminishing. The model they developed can be used to decide the solution of selling vessels to maximize the present net assets. First, it can determine the selling sequence of the vessels; then it determines the type and number of vessels to sell and to take on lease every year by using dynamic programming. However, this model considers only the retirement of

vessels in the planned time horizon, not the expansion of fleet. So this model only fits for those large shipping companies who want to exit from shipping industry or reduce the ships they own.

A. N. Perakis and D. I. Jaramillo pointed out that under the situation of the existence of reliable cargo turnover prediction, some known mathematic optimization methods such as linear programming, non-linear programming and integer programming can be used to solve the problem of fleet deployment planning. Also, they applied these methods to the fleet deployment planning of a large American liner shipping company.

Krishan Rana and R. G. Vickson used Lagrangean relaxation and decomposition to establish a model which mixed integer programming and non-linear programming together for the purpose of optimizing the routing problem under the situation of multi-ports and multi-types of vessels. The model was successful in theory, but it was too complex. Not all the people can master it except he is a specialist.

Professor Xie Xin-lian did another research on the problem of fleet deployment planning. He combined linear programming and dynamic programming together to solve the optimal development strategy and routing problem of a fleet during a time period of several consecutive years. The problem can be divided into two sub-problems. One is using linear programming to solve the optimal routing plan of the year under the situation of certain fleet and transportation task. Another is applying dynamic programming to solve the optimal development strategy of the fleet each year. Using this model, the optimal development strategy of the fleet (how many ships of each type should be acquired) can be gained when computing out the optimal routing plan of the fleet at the same time.

2. ANALYSIS OF CRUDE OIL MARKET

2.1. Analysis of World Oil Market

2.1.1. Analysis of World Crude Oil Reserves

According to BP Statistical Review of World Energy 2005, at the end of 2004, world proved reserves of oil[1] was about 1190 thousand million barrels. Figure 1 reveals the geographical distribution of proved oil reserves of the world. Middle East, with 733.9 thousand million barrels of proved oil reserves, is still the area that has the most abundant crude oil resources. There are 139.2 thousand million barrels of proved oil reserves in Europe & Eurasia which is about 1/5 of that in Middle East, makes it the second oil plenteous area. Africa, with 112.2 thousand million barrels of proved oil reserves, becomes the third. S. & Cent. America, with 101.2 thousand million barrels of proved oil reserves, is the fourth. North America and Asia Pacific, with a proved oil reserves of 61 and 41.1 thousand million barrels, rank last two in figure 1.

[1] Proved reserves of oil - Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

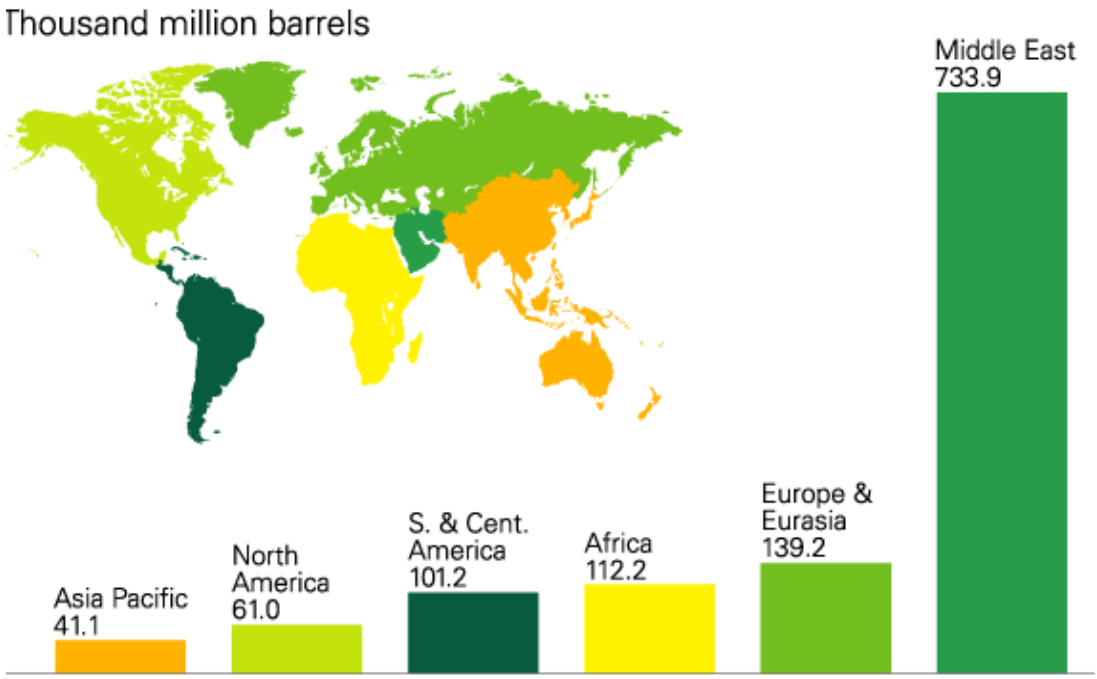

Figure 1: Proved Oil Reserves of the World (at end 2004)

Source: BP. (2005). Statistical Review of World Energy 2005

Table1: Proved Oil Reserves of the World (at end 2004)

	Proved Oil Reserves (Thousand million barrels)	Share of total	R/P ratio (years)
Total Middle East	733.9	61.7%	81.6
Total Europe & Eurasia	139.2	11.7%	21.6
Total Africa	112.2	9.4%	33.1
Total S. & Cent. America	101.2	8.5%	40.9
Total North America	61.0	5.1%	11.8
Total Asia Pacific	41.1	3.5%	14.2
TOTAL WORLD	**1188.6**	**100.0%**	**40.5**
Of which OECD	82.9	7.0%	10.9
OPEC	890.3	74.9%	73.9
Non-OPEC (£)	177.4	14.9%	13.5
Former Soviet Union	120.8	10.2%	28.9
£ Excludes Former Soviet Union			

Source: BP. (2005). Statistical Review of World Energy 2005

Doing some simple calculation, we can find that more than 60% of the world total oil reserves are in Middle East, the R/P ratio[2] is 81.6 years; Europe and Eurasia own 11.7% of the world total oil reserves and the R/P ratio is 21.6 years; Africa, S. & Cent. America, North America and Asia possess 3.5% - 9.4% of the world total oil reserves respectively, and their R/P ratio count from 11.8 – 40.9 years depending on different production rates. The statistics also shows that 74.9% of the world proved oil reserves are located in OPEC countries; 14.9% in Non-OPEC countries, excluding Former Soviet Union countries; 10.2% in Former Soviet Union and 7.0% in OECD countries. (See table 1)

Table 2: Top 12 Oil Abundant Countries in the World

Rank	Country	Proved Oil Reserves (Thousand million barrels)	Share of total	R/P ratio (years)
1	Saudi Arabia	262.7	22.1%	67.8
2	Iran	132.5	11.1%	88.7
3	Iraq	115	9.7%	> 100
4	Kuwait	99	8.3%	> 100
5	United Arab Emirates	97.8	8.2%	> 100
6	Venezuela	77.2	6.5%	70.8
7	Russian Federation	72.3	6.1%	21.3
8	Kazakhstan	39.6	3.3%	83.6
9	Libya	39.1	3.3%	66.5
10	Nigeria	35.3	3.0%	38.4
11	USA	29.4	2.5%	11.1
12	China	17.1	1.4%	13.4

Source: BP. (2005). Statistical Review of World Energy 2005

Table 2 lists the main countries that have a large amount of proved oil reserves. It can be seen in the table that the top 5 countries are all Middle East countries. They

[2] Reserves/Production (R/P) ratio - If the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that level.

possess almost 60% of the total proved oil reserves in the world. Besides Middle East countries, there are some other countries have considerable oil reserves. Venezuela in South America and Russian Federation in Eurasia, own 77.2 and 72.3 thousand million barrels of oil reserves, about 6% of the world total each. Kazakhstan in Eurasia, Libya and Nigeria in Africa, own 35 - 40 thousand million barrels of oil reserves, about 3% of the world total amount. United States of America possesses 2.5% of world total oil reserves and China owns 1.4%.

Middle East, a place where the crude oil resources is the most substantial in the world, will still be the center of oil supply in the future.

2.1.2. Analysis of World Crude Oil Supply/Demand

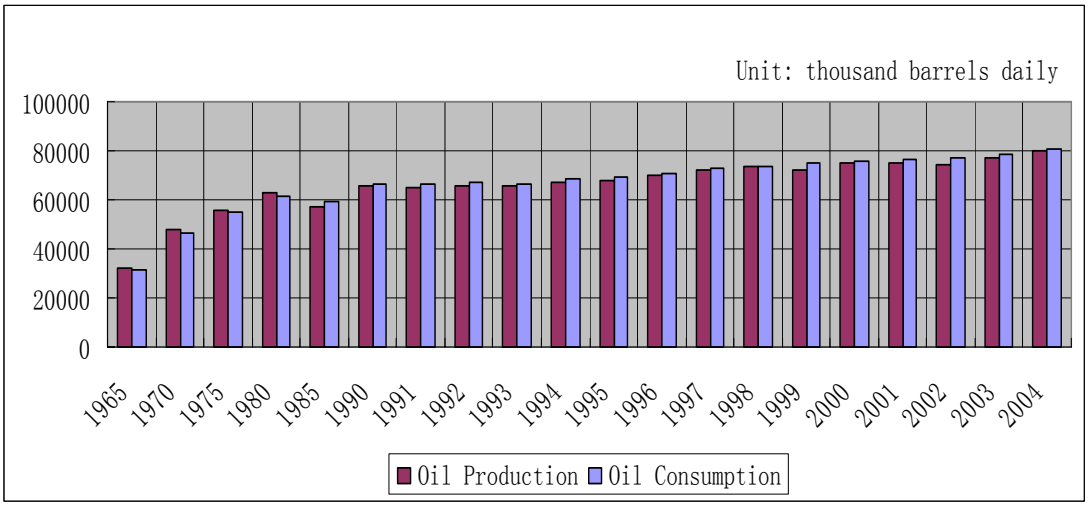

Figure 2: Oil Production and Consumption of the World

Source: BP. (2005). Statistical Review of World Energy 2005

The data from BP Statistics Review of World Energy 2005 shows the world production and consumption of crude oil from 1965 to 2004. (See Figure 2) The oil

production and consumption were continuously increasing during the last 40 years. The average growth rate of oil production is about 2.4% while that of oil consumption is approximately 2.46%. Consumption grows a little bit faster than production. At the end of year 2004, the production was 80,260 thousand barrels per day and the consumption was 80,757 thousand barrels daily. Before 1980s, the daily consumption was a little bit smaller than production. And after 1980s, the daily consumption of crude oil started to exceed the production. The supply of crude oil is able to satisfy the demand in the rough.

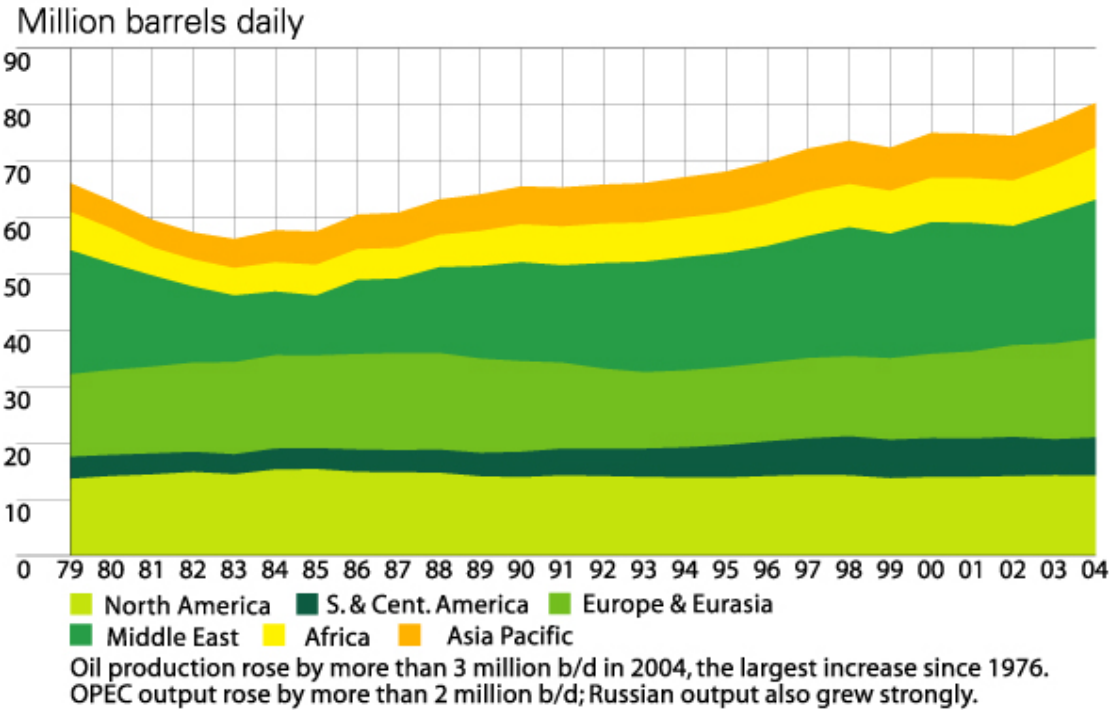

Figure 3: Oil Production by Area

Source: BP. (2005). Statistical Review of World Energy 2005

At the end of 2004, world total oil production was 80,260 thousand barrels per day, of which OPEC produced 32,927 thousand barrels per day, account for 41.1%; OECD produced 20,732 thousand barrels per day, account for 25.3%; Former Soviet

Union produce 11,417 thousand barrels per day, account for 14.4% and other countries produce 35,916 thousand barrels per day, account for 44.5%. In the last few years, the increment of oil production was mainly from OPEC and Former Soviet Union countries. From 2000 to 2004, OPEC increased its production by about 5%, and Former Soviet Union countries increased their production by about 42%, of which Russia account for the most. Figure 3 illustrates the oil production by area.

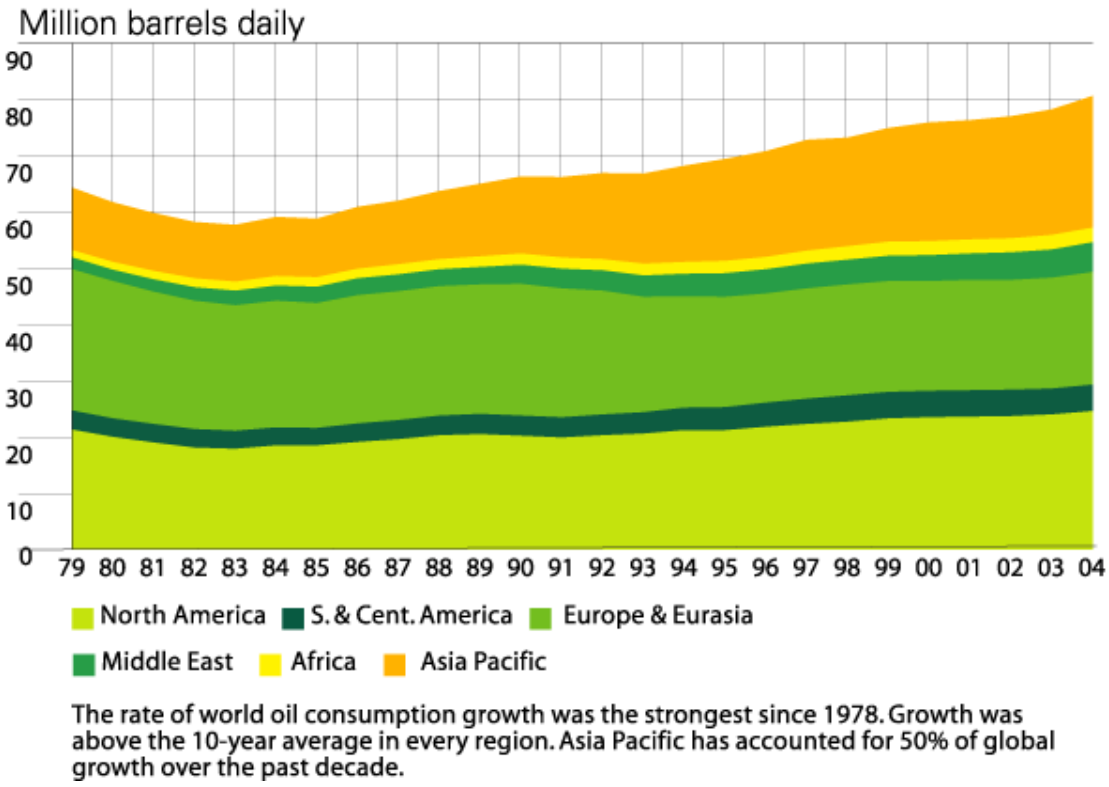

Figure 4: Oil Consumption by Area

Source: BP. (2005). Statistical Review of World Energy 2005

The world consumption of oil was 80,757 thousand barrels daily at the end of 2004, of which North America, Europe & Eurasia and Asia Pacific occupy most percentage of the consumption. (See Figure 4) During the last 20 years, the increment of consumption comes most from Asia Pacific and North America, of which China and

USA are the two main consumers.

Among all the oil consumers, OECD countries used up almost 60% of the total consumption. Emerging Market Economy (EME) countries occupy about 35%, and their consumption of crude oil grows the most quickly in the world, especially China. EU countries account for about 18% of the consumption and Former Soviet Union countries take up 5%.

2.1.3. Analysis of World Crude Oil Import/Export

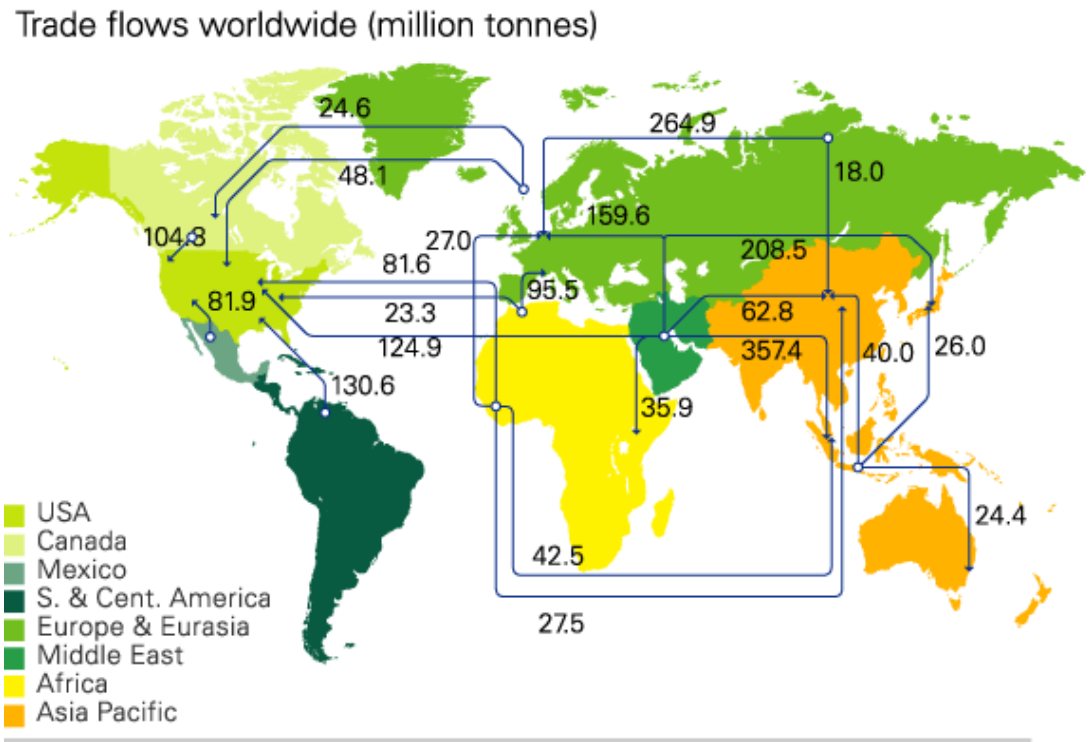

Figure 5: Major Oil Trade Movements

Source: BP. (2005). Statistical Review of World Energy 2005

Figure 5 demonstrates the major oil trade movements of the world. There are 4

main areas that export crude oil: Middle East, Former Soviet Union, West Africa and South America. According to the statistics of BP, in 2004, about 40% of the oil trade was from Middle East; 13.4% of the export was from Former Soviet Union countries; 8.4% of the export was from West Africa and 6.7% from South & Central America. These years, the export of oil from Middle East was comparatively steady. By contrast, the export from Former Soviet Union countries and West Africa grew at a great speed. For some political and secure considerations, more and more countries are searching for new oil suppliers outside Middle East.

The main regions that import crude oil are North America, West Europe and Asia Pacific. USA is the largest oil importing country in the world, which imported 26.8% of the world total import of crude oil in 2004. Japan and China are the two large oil importing countries next to USA, imported about 20% of the world total import of crude oil in 2004. West Europe, where many developed countries located, imported about 26% of the world total import of crude oil in 2004.

2.2. Analysis of China's Oil Market

With the rapid development of the economy of China, the demand for crude oil is becoming larger and larger. Now, the crude oil consumption of China is just next to USA, becomes the second in the world.

2.2.1. Analysis of China Crude Oil Reserves

According to BP Statistical Review of World Energy 2005, at the end of 2004, world proved reserves of oil was about 1,190 thousand million barrels, R/P rate was 40.5

years. The proved oil reserves of China are 17.1 thousand million barrels, occupy 1.4% of the world reserves, and rank the 11th in the world. The R/P rate of China is 13.4 years. (See Table 1 and Table 2)

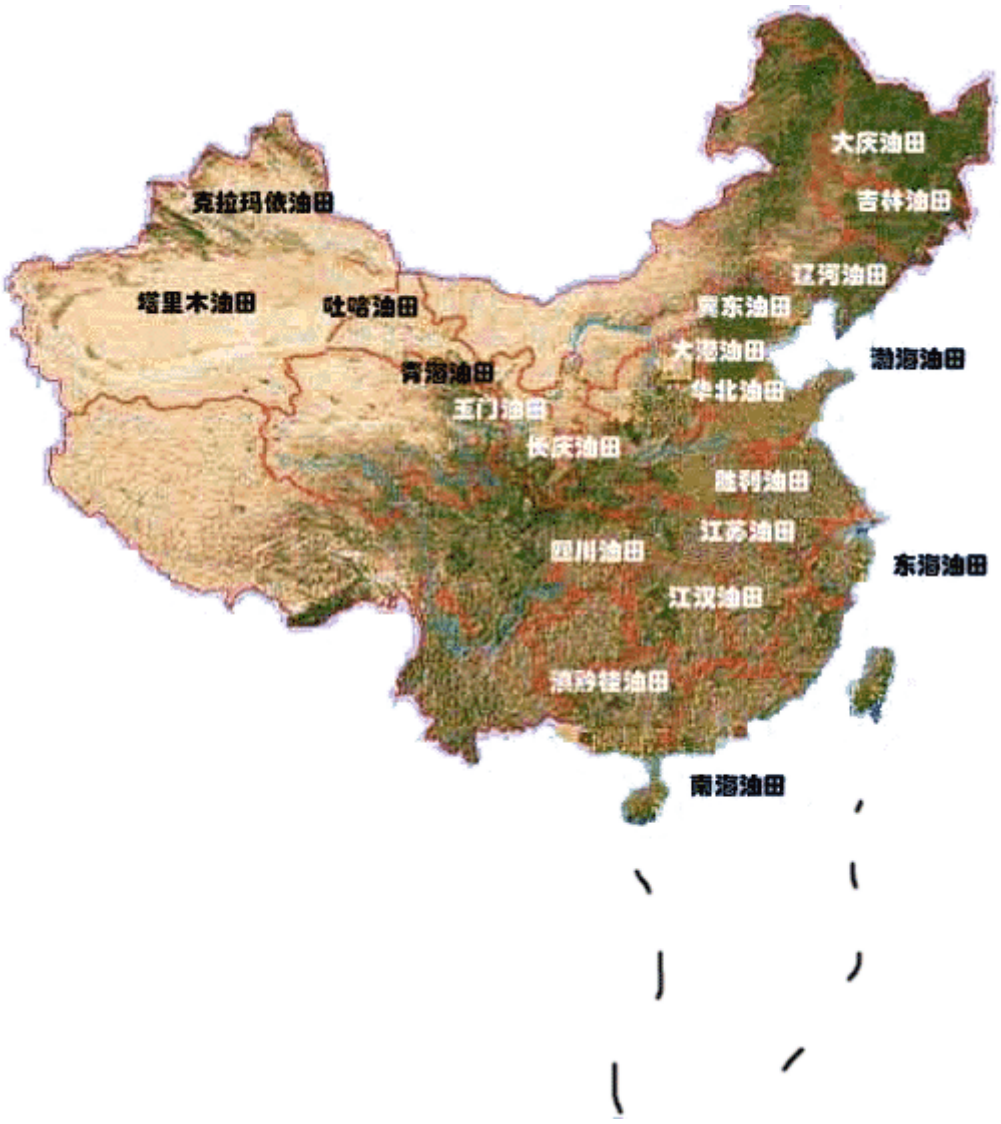

Figure 6: Distribution of Oil Resources in China

Source: http://www.oilgas.com.cn/News/NewsItem.aspx?id=20636

Figure 6 shows the distribution of oil resources in China. The oil resources in China distribute mainly in the north-east, middle-east and north-west of China. But

in the south area of China, oil resources are very limited, where the scales of the oil fields are all small. More than 90% of the oil resources in China are distributed in the north area of China, that is, north to the Yangtze River.

According to the words of a researcher of The Ministry of Land and Resources P.R.C, the reserves of oil resources of China are still growing, though the speed is very low. The production of oil is increasing as well as the exploration of proved oil reserves. So the R/P rate of China can be remained as 14-16 years since 1993, when China became an oil importing country.

There is a trend in the distribution of oil resources in china that the center of proved oil reserves is moving from the east to the west of China. In the last 5 years, the oil exploration shows that the reserves of oil resources in the west area of China are growing very fast. From the establishment of People's Republic of China, 72% of the accumulative oil reserves are in the east area. But from the year 2000 to 2005, the proved reserves of oil in the east area has reduced from 72% to 47%, and that of west rise from 28% to 53%. (Hua-sheng Newspaper, 2005)

2.2.2. Analysis of China Crude Oil Supply/Demand

1. Crude Oil Production in China

From 1990 to 1997, the production of crude oil kept growing at an annual rate of 2.8%. The production went up from 138.3 million tons in 1990 to 160.7 million tons in 1997. In 1998 and 1999, the production was reduced a little, which was 159.1 and 159.5 million tons respectively. After 2001, the production started to rise slowly again and in 2004, the production reached 174.5 million tons. In 2005 the

production of crude oil in China is 180.83 million tons. The production of crude oil in China will not have breakthrough in the next ten years and it can only maintain the level of 1.8 million tons per year and a slightly growth. There are two main reasons for the slow growth of crude oil production in China. Firstly, the comparatively small oil reserves of China limits the production. The oil reserves of China are not very abundant in the world and the oil reserves per capita are about 10 tons, ranked No.41 in the world. And the R/P rate of China is much lower than that of the world average too. Secondly, the new discovered oil fields are usually in areas that difficult to exploit. With the exhaustion of the old generation of oil fields in the east area of China, the production is more and more dependent on the new discovered oil fields in the west area of China and on the continental shelf. However, the environment of those places is geologically complex and it is hard for people to exploit both technically and financially. That restricts the growth of crude oil production to some extent.

2. Crude Oil Consumption in China

For the last two decades of years, the crude oil productions of China were all above 100 million tons per year and kept an average annual growth rate of 1.65%. The production of crude oil in 1998 was 159.1 million tons

From 1978 to 1990, the China's demand for crude oil grows steadily. The amount of consumption rose from 91.3 million tons in 1978 to 110.3 million tons in 1990, with an average growth of 1.58 million tons per year and an average annual growth rate of 1.6%. After 1991, the economy of China kept a fast growth rate as well as the crude oil consumption. The amount of consumption rose from 110 million tons in 1990 to 290 million tons in 2004, with an average growth of 12 million tons per

year and an average annual growth rate of 6.68%. From 2001 to 2004, the growth speed accelerated further. The crude oil consumption was 290 million tons in 2004, grew by 76.58 million tons in comparison with that in 2001 and the average annual growth rate was nearly 8%.

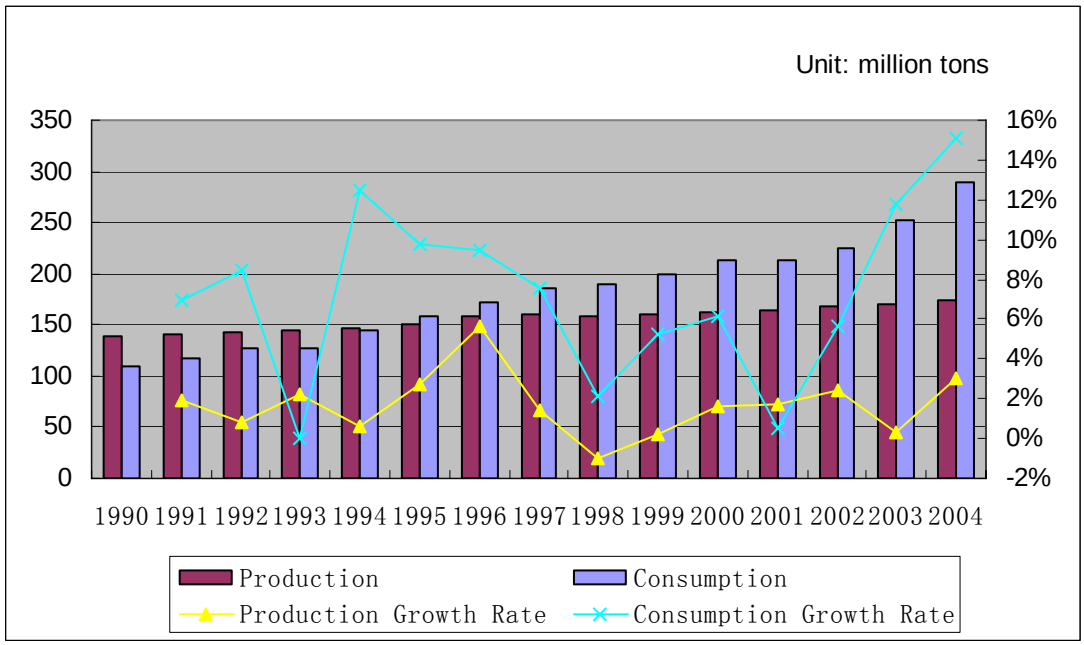

Figure 7: Production and Consumption of Crude Oil in China

Source: Chinese Energy Statistics, National Bureau of Statistics of China and Maritime Information

2.2.3. Analysis of China Crude Oil Import/Export[3]

Since 1970's, for almost 20 years, China had been a net exporter of crude oil. At the end of 1980s, because of the rising of national economy and the higher requirement of environmental protection, the demands for crude oil took on a trend of increasing, thus from the year 1988, our country began to import crude oil from foreign countries. In 1992, oil market in China was liberated. After that, with the

[3] Data are collected from the annual statistic reports published by National Bureau of Statistics of China

further increasing of the economy of China, the consumption of oil is also going up, which attribute to the awfully increasing of domestic demands for oil that even can't be satisfied by domestic oil production. The gap between demand and supply of crude oil will be bigger and bigger, and it will be the trend that the supply of crude oil in China has to depend on import. It was in 1993 that the phenomenon of net import of petroleum and petroleum products appeared. China became a net importer of petroleum and petroleum products instead of a net exporter. With the steady increasing of petroleum import, the export amount of crude oil decreases. When it is comes to the year 1996, there was a historical turning point for the balance of production and demands of petroleum in China. In that year, the imported amount of crude oil was 22.62 million tons, while the exported amount of crude oil was 20.329 million tons, China changed from a net exporter of crude oil to a net importer of crude oil. During the next few years, the imported amount of crude oil took on a trend of increasing year after year. In 1999, the figure of Chinese crude oil import was 36.61 million tons which accounted for 20.8% of the national crude oil consumption. In the year 2000, the quantity of imported crude oil increased by 91.6% than that in 1999, which reached 70.27 tons and accounted for 33.2% of the national crude oil consumption. As the amount of import was too much in 2000, the crude oil could not be consumed within the year. The inventory of surplus crude oil was kept and results in the reduction of crude oil import in 2001, which was 6026 million tons, 14.25% less than that of the year before. In 2002, China's import of crude oil rose by 15.8%, which was 6941 million tons. The number was rocketed again in 2003 and 2004, reached 91.12 million tons and 122.72 million tons with the increasing rate of 31.28% and 34.68% respectively. It is abnormal as it is affected by some special factors such as the war in Iraq. In 2005, these factors are disappearing and the increasing rate of crude oil import of China is normalizing gradually.

At present, China is the biggest oil producing country in Asia Pacific as well as the second biggest crude oil importer in the world. The increasing of oil consumption together with the lag of increasing of production in China leads to the high dependency on international oil market. With the rising import of crude oil, the degree of dependency on the international market of crude oil consumption in China raised from 10.8% in 1995 to 42.3% in 2004. With the development of national economy, the requirement for petroleum and petroleum products is blooming. In the coming 10 years, the increasing speed of domestic crude oil production is less than half of increasing speed of crude oil consumption. The gap between production and consumption will be enlarged gradually. The self-support ratio of crude oil in China has decreased to less than 50%. The big gap can only be filled in by importing from international crude oil market. With the fast increasing of demand for petroleum, self-support ratio of crude oil is decreasing year by year. A simple fact is that it has become an irreversible trend that China will import more and more crude oil from outside.

3. PREDICTION OF THE AMOUNT OF IMPORTED CRUDE OIL OF CHINA

After the analysis of crude oil market in chapter 2, the situation of the market can be known about. China imports crude oil mainly from Middle East, South Africa and South East Asia. Additionally, Former Soviet Union is another source of crude oil for China just next to the 3 main areas. The amount of China's crude oil import is increasing year by year. In this chapter, the prediction of the amount of imported crude oil of our country for the next 10 years (till 2015) will be conducted using quantitative method and adjusted by qualitative analysis.

3.1. Quantitative Analysis of the Crude Oil Import of China

There are many methods of quantitative analysis such as time-series models， regression models, theory of grey system and so on. To determine which of these methods are to be applied, the data should be analyzed first.

Table 3 shows the amount of imported crude oil of China from 1988 to 2005. Through the observation of the data, it can be seen that with the time goes by, the amount of import has a clear long-term upward trend. From 1988 to 2005, the import went up continuously from 0.855 million tons to 126.82 million tons. Based on such a character, Extrapolation of Time Series can be used to make prediction. Additionally, Regression Model is suitable for this type of data as well. Therefore,

in this paper, time-series models and regression models are used to make forecast for the future import of crude oil in China.

Table 3: The Amount of Imported Crude Oil of China (1988-2005)

Sequence	Year	Amount of Import (million tons)	Sequence	Year	Amount of Import (million tons)
1	1988	0.855	10	1997	35.47
2	1989	3.263	11	1998	26.8
3	1990	2.923	12	1999	36.61
4	1991	5.793	13	2000	70.27
5	1992	11.36	14	2001	60.26
6	1993	15.67	15	2002	69.41
7	1994	12.34	16	2003	91.12
8	1995	17.09	17	2004	122.72
9	1996	22.62	18	2005	126.82

Source: National Bureau of Statistics of China

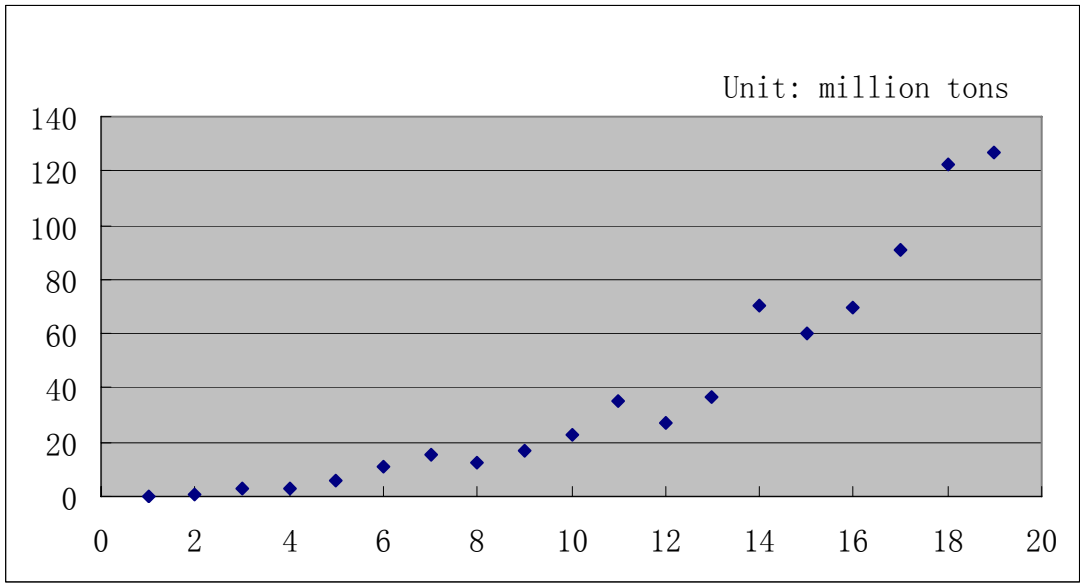

Figure 8: The Amount of Imported Crude Oil of China (1988-2005)

Time-series models are used to predict future movements in a variable based solely

on the past behavior of that variable. The main time-series models are trend extrapolation model, exponential smoothing model, moving average model etc. This method is suitable for short-term and mid-term forecast. In this paper, Linear Curve Forecast Model will be applied.

Regression models are used to predict future value of a variable based on the historical performance of the variable itself and some other related variables to explain the movements. It is also called cause-and-effect model. This method is applicable for all kinds of predictions, not only short term, but mid-term and long-term as well. In this paper, Quadratic Curve Regression Model will be used.

3.1.1. Linear Curve Forecast Model

Here, linear curve forecast model will be used. The model is a linear equation like the formulation (3-1) shown below.

$$Y_t = b_0 + b_1 t \qquad (3\text{-}1)$$

in which Y_t is the forecast value of the amount of imported crude oil of China;

t is the sequence number of the year (set the year 1988 as 1 and analogize);

b_0 and b_1 are the coefficients.

By using the software Microsoft Excel, the coefficients can be computed out:

$b_0 = -25.693$

$b_1 = 6.9817$

So the model can be regressed as formula (3-2):

$$Y_t = - 25.693 + 6.9817\ t \qquad (3\text{-}2)$$

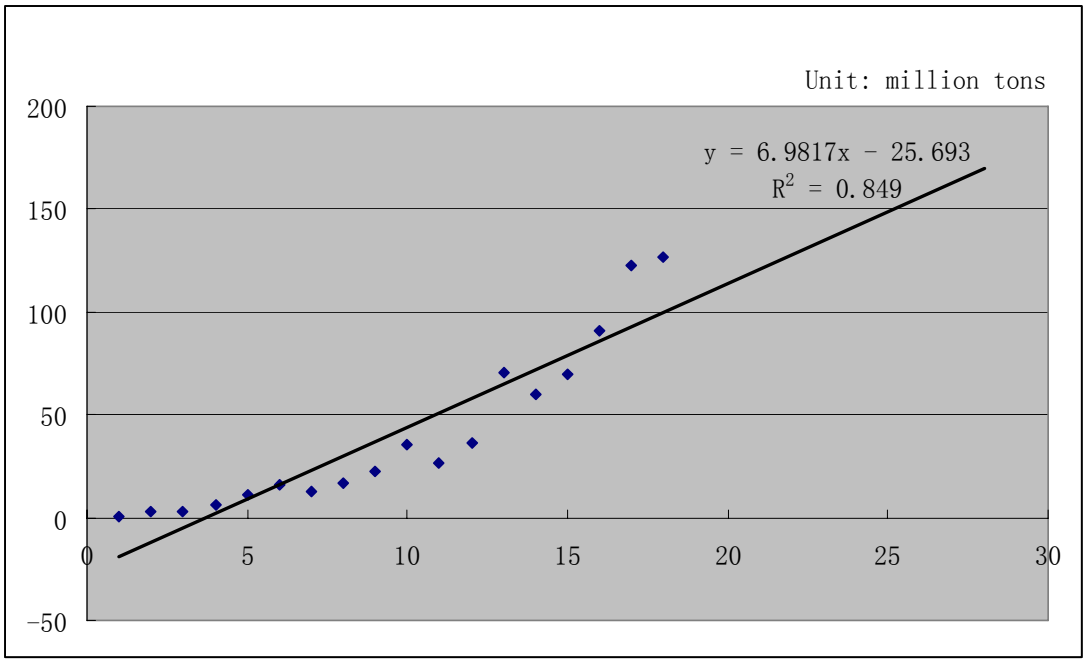

Figure 9: Linear Curve Forecast of Crude Oil Import of China

And the $R^2 = 0.849$, which means that the cubic curve has an acceptable degree of fitting for the historical data. (See Figure 9)

Accordingly, by substituting the corresponding time series numbers for 't', we can gain the result of the forecast value as shown in the table 4. The quantity of imported crude oil of China is predicted to be 169.79 million tons in the year of 2015.

Table 4: The Result of Forecast by Linear Curve Model

Time Series	Year	Amount of Import (million tons)	Time Series	Year	Amount of Import (million tons)
19	2006	106.96	24	2011	141.87
20	2007	113.94	25	2012	148.85
21	2008	120.92	26	2013	155.83
22	2009	127.90	27	2014	162.81
23	2010	134.89	28	2015	169.79

3.1.2. Quadratic Curve Regression Model

Table 5 demonstrates the GDP and Amount of Imported Crude Oil of China from 1988 to 2005. From the table, we can see that the import of crude oil goes up continuously. And it is the rise of demand that makes the oil import increase. The reason for the rise demand for crude oil is that the economy of China grows at a fast speed. So we can say that the high growth rate of the amount of imported crude oil in China is highly related to the fast economic growth of China.

Table 5: GDP and Amount of Imported Crude Oil of China (1988-2005)

Year	GDP (b. RMB)	Import (m.tons)	Year	GDP (b. RMB)	Import (m. tons)
1988	1492.83	0.855	1997	7897.3	35.47
1989	1690.92	3.263	1998	8440.2	26.8
1990	1854.79	2.923	1999	8967.7	36.61
1991	2161.78	5.793	2000	9921.5	70.27
1992	2663.81	11.36	2001	10965.5	60.26
1993	3533.4	15.67	2002	12033.3	69.41
1994	4819.8	12.34	2003	13582.3	91.12
1995	6079.4	17.09	2004	15987.8	122.72
1996	7117.7	22.62	2005	18232.1	126.82

Source: National Bureau of Statistics of China

In order to prove the above viewpoint, let's make a Bivariate Correlations Analysis between GDP and Amount of Imported Crude Oil in China during the period 1988-2005. Using the software Statistical Product and Service Solutions (SPSS) to make this analysis, we can see in the output (See table 6) that the correlation between the two variables is 0.964, which means that they are highly related to each other.

Table 6: Bivariate Correlations Analysis between GDP and the Crude Oil Import of China

Correlations			
		GDP	Amount of Import
GDP	Pearson Correlation	1	0.964
	Sig. (2-tailed)	.	0.000
	N	18	18
Amount of Import	Pearson Correlation	0.964	1
	Sig. (2-tailed)	0.000	.
	N	18	18
** Correlation is significant at the 0.01 level (2-tailed).			

As the GDP and the Amount of Imported Crude Oil in China is highly related to each other, the Amount of Imported Crude Oil can be considered as a dependent variable changing with the independent variable GDP. Thus, a one-variable regression equation can be formed. After many trials and errors, the quadratic equation, like formula (3-3) shown below, is proved to be the most fitting curve for the regression.

$$Y_x = b_0 + b_1 x + b_2 x^2 \qquad (3\text{-}3)$$

In which Y_x is the forecast value of the amount of imported crude oil of China;

x is the correlated factor (here is GDP);

b_0, b_1 and b_2 are the coefficients.

By using SPSS, the coefficients can be computed out:

$b_0 = -2.937$

$b_1 = 0.0027$

$b_2 = 0.00000028$

So the model can be regressed as formula (3-4):

$$Y_x = (-2.937) + 0.0027\,x + 0.00000028\,x^2 \qquad (3\text{-}4)$$

And the $R^2 = 0.962$, which means that the curve has a very high degree of fitting for the historical data.

Because GDP is selected as the independent variable, before making prediction of the amount of imported crude oil for the next 10 years, the GDP of China of the next 10 years should first be estimated.

Table 7: The Result of Forecast by Regression Model

Year	Growth Rate	GDP (billion RMB)	Amount of Import (million tons)
2006	5.3%	19198.40	152.10
2007	5.3%	20215.92	166.08
2008	5.3%	21287.36	181.42
2009	5.3%	22415.59	198.27
2010	5.3%	23603.62	216.79
2011	5.3%	24854.61	237.14
2012	5.3%	26171.90	259.52
2013	5.3%	27559.01	284.13
2014	5.3%	29019.64	311.22
2015	5.3%	30557.68	341.02

According to the stratagem posed on the 16th National Congress of the CPC held in November 2002, the GDP of China in 2020 was planned to be quadrupled in comparison with that in 2000. That is, the GDP of China should keep an average annual growth rate of 7.2% from 2000 to 2020. Considering the high GDP growth rate in the first 5 years of the 21st century, the growth rate of 7.2% is too big for the planned growth of economy. Using the formula $9921.5 \times 4 = 18232.1 \times (1 + g)^{15}$, the GDP growth rate of the next 15 years (2006-2020) can be obtained. So here I assume that the GDP of China will keep an annual growth rate of 5.3% during the period from 2006 to 2015. Accordingly, by substituting the corresponding GDP for 'x', we can gain the result of the forecast value as shown in the Table 7 and Figure 10.

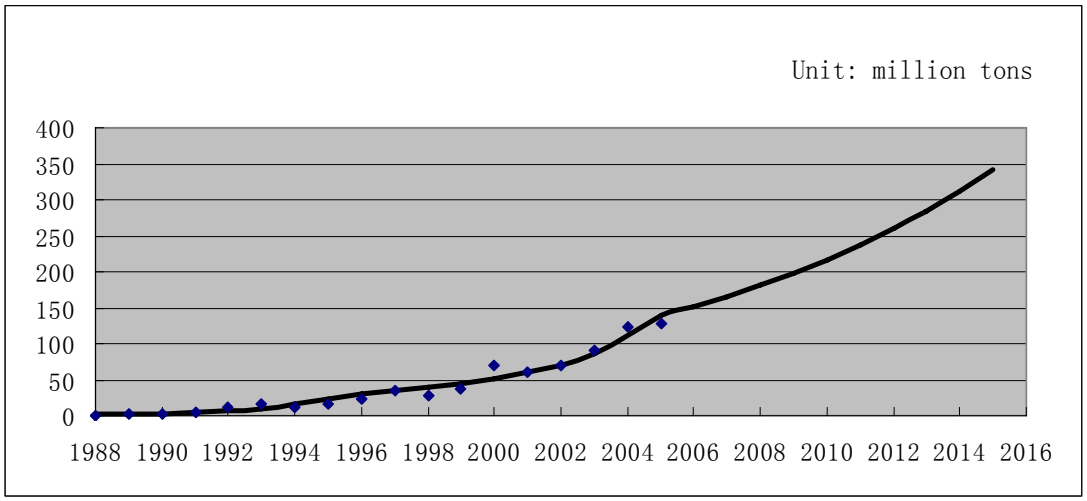

Figure 10: The Result of Forecast by Regression Model

3.1.3. Synthesis of the Quantitative Analysis

To combine the results coming from the two different forecast methods, a new equation is formed [Formula (3-5)].

$$Y = \sum (W_1 \times Y_t + W_2 \times Y_x) \qquad (3\text{-}5)$$

In which Y_t is the result coming from the Polynomials Curve Forecast Model;

Y_x is the result coming from the Regression Model;

W_1 is the weight assign to the Y_t;

W_2 is the weight assign to the Y_x.

To decide the value of the weight of Y_t and Y_x, linear programming is applied here. Set Y_a as the actual historical value of the crude oil import of China, then $[Y_a - \sum (W_1 \times Y_t + W_2 \times Y_x)]^2$ reflects the dispersion degree between the actual values and forecast values. To make a more accurate prediction, the less the dispersion degree is, the better the forecast will be. And the linear programming problem can be formed as shown below:

$$\text{Min} \sum [Y_a - \sum (W_1 \times Y_t + W_2 \times Y_x)]^2 \qquad \text{(object function)}$$

s.t:

$$\begin{cases} W_1 + W_2 = 1 & \text{(constraint)} \\ 0 \le W_1, W_2 \le 1 & \text{(constraint)} \\ \sum (W_1 \times Y_t + W_2 \times Y_x) \text{ in } 2005 = Y_a \text{ in } 2005 & \text{(constraint)} \end{cases}$$

Because the quantity of imported crude oil of China in 2003 and 2004 was abnormally high and the quantity in 2005 was back to the normal level, the third constraint is added here. By using the spreadsheet of Microsoft Excel, the linear programming problem can be solved.

$$\begin{cases} W_1 = 0.32 \\ W_2 = 0.68 \end{cases}$$

Table 8: The Synthesis of the Quantitative Analysis Unit: million tons

Year	Linear Curve (Y_t)	Regression (Y_x)	Combination (Y)	Weights
2006	106.96	152.10	137.72	
2007	113.94	166.08	149.47	
2008	120.92	181.42	162.15	
2009	127.90	198.27	175.86	
2010	134.89	216.79	190.70	$W_1 = 0.32$
2011	141.87	237.14	206.80	$W_2 = 0.68$
2012	148.85	259.52	224.27	
2013	155.83	284.13	243.27	
2014	162.81	311.22	263.95	
2015	169.79	341.02	286.49	

3.2. Qualitative Analysis of the Crude Oil Import of China

Since the international situation is changeable, there are many factors that will influence the crude oil import of China is hard to be contained in the quantitative forecast model. Next, these factors will be discussed.

3.2.1. The Influence of Economy

Firstly, it is no doubt that the fast development of the economy of China will influence the consumption of oil and then stimulate the import of crude oil. Figure 11 shows the influence of economy on the crude oil import.

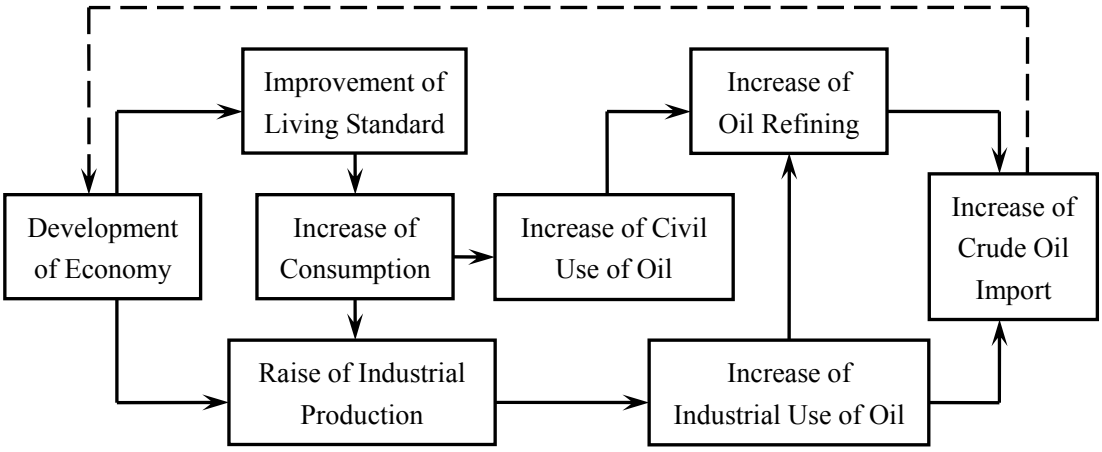

Figure 11: The Influence of Economy on the Crude Oil Import

In China, most of the crude oil is used to refine and produce product oil and chemical products. These products are mostly for domestic use. Only a fraction of them are exported to other countries in the world. With the development of the economy, the incomes of the people and the standard of living will be improved as well. The development of the industry of communication and transportation including family cars will then be boosted. At the same time, the civil and industrial oil consumption will increase sufficiently. As far as the economy of China develops, the oil consumption will grow. On the other hand, the increase of oil consumption will stimulate the development of economy. It is forecasted that the economy of China will develop at a fast speed in the next ten years, so the oil consumption and crude oil import will increase in the future.

3.2.2. The Influence of Refining Capacity

Secondly, the enhancement of oil refining capacity of China will bring about the increase of crude oil import. After over 50 years' development, the oil refining industry of China has achieved a great scale and a complete industrial system. In

2005, the primary processing capacity of China has reached 328 million tons per year and practically processed 286 million tons in that year. It can be seen that about 12% of the capacity was not be well used. That is partially because of the insufficient supply of crude oil. To make full use of the oil processing capacity, increase the crude oil production and import is necessary. And according to the "Mid-long Term Special Planning for Oil Refining Industry" published on the official website of the National Development and Reform Commission of China, during the eleventh five-year period (2006-2010), the crude oil processing capacity will increase by 90 million tons, in which 68 million tons in Guang-dong Province, 14 million tons in Hu-bei Province and over 10 million tons in Hu-nan Province and He-bei Province. With the increase of oil processing capacity, the crude oil import will increase certainly.

3.2.3. The Influence of Strategic Petroleum Reserve

Thirdly, China is now starting to develop the strategic petroleum reserve system. Many strategic petroleum reserve bases are under construction and some are nearly completed. So the imported crude oil of China is likely to increase at a considerable degree in the short term.

These years, the degree of dependency of the economy of China on petroleum is becoming larger and larger. In 2004, China import 122.72 million tons of crude oil, account for 42.3% of the annual total crude oil consumption. Because of the increase of the uncertainty of the international situation and the turbulence of the situation in oil production area, it is difficult to ensure a stable and durable import channels in the long term. Besides, there is a serious scarcity of the oil reserve facilities in China, of which the capacity of reserve is less than 30 days in theory.

Therefore, to guarantee the security of energy resources and keep a stable environment of development, it is extremely necessary for China to build the strategic petroleum reserve system.

It is at the fourth session of the ninth National People's Congress in March 2001, Premier Zhu Rong-ji formally proposed to develop strategic petroleum reserve in China for the first time. And now, China will initialize the strategic petroleum reserve at the end of 2006. Selected by the National Development and Reform Commission, the first four places where main national strategic petroleum reserve bases are located are in Zhen-hai of Zhe-jiang Province, Dai-shan of Zhe-jiang Province, Huang-dao of Shan-dong Province and Da-lian of Liao-ning Province respectively. The strategic petroleum reserve base in Zhen-hai of Zhe-jiang Province is considered as the largest one among the four and its constructing progress is the fastest. The base in Zhen-hai which was begun constructing in October 2004, will complete its construction (phase I) in 2006. At that time, the petroleum reserve capacity of the base will achieve 5 million cubic meters. Besides the base in Zhen-hai, the other 3 bases are now speeding up their construction. The three largest oil companies in China, China Petroleum & Chemical Corporation (SINOPEC), China National Petroleum Corporation (CNPC) and China National Offshore Oil Corporation (CNOOC), are entrusted by the government of China to take charge of the construction of the project. And it is estimated that the phase I construction of the four petroleum reserve bases in Zhen-hai, Dai-shan, Huang-dao and Da-lian will be completed before 2008 in succession.

Presently, China doesn't have any strategic petroleum reserve. There only has some commercial petroleum reserve mainly by the two large Chinese oil companies SINOPEC and CNPC, of which the amount of reserve can only maintain the use for

21.6 days. Without enough strategic petroleum reserve, China has no bargaining power in the international oil trade market. China has to purchase the oil no matter how high the oil price is. After the completion of the four main national strategic petroleum reserve bases, the total capacity of strategic petroleum reserve will reach 30 days. Together with the 21.6 days' commercial petroleum reserve, the total petroleum reserve capacity of China will achieve an acceptable scale. In comparison, for America, Japan, Germany and France who have already established mature strategic petroleum reserve systems, their petroleum reserve kept by the government, together with the private reserve, can maintain the use for 158 days, 161 days, 117 days and 96 days respectively. (Wang Hong-sheng, 2006) And the standard of strategic petroleum reserve suggested by International Energy Agency (IEA) for its member countries is 90 days' net import of petroleum. Taking this standard as reference, the long-term goal of the strategic petroleum reserve of China is 90 days too. It is estimated that the goal is not able to achieve until 2015. So there is still a long way to go.

According to the analysis above, it is safe to say that during the next ten years (2006-2015), the imported crude oil of China will be higher than usual since the petroleum reserve bases will be filled up gradually.

3.2.4. The Influence of Substitutes

Fourthly, the use of substitutes for oil products will reduce the crude oil import of China. Official information comes from the government of China shows that from the year 2010 to 2020, resources saving strategy will be implemented to reduce the intensity of petroleum consumption by generalizing the use of substitute for petroleum. However, petroleum is still the most popular energy resource widely

used in the world, so the generalizing of substitute for petroleum can only slightly reduce the crude oil import of China.

3.2.5. The Influence of Other Channels of Import

Lastly, other channels of import such as pipelines will affect the waterway import of crude oil. Besides waterway crude oil import, another main crude oil import channel is by pipeline. Presently, there are two large pipelines which will be used to import crude oil are under construction.

One is the line between Kazakhstan and China with a total length of 1000 kilometers. China National Petroleum Corporation (CNPC) and PetroKazakhstan Inc. take charge of the project together. The phase I project can afford a 10 million tons' annual transport capacity and is completed at the end of 2005. Phase II project will complete in 2011 and the capacity of transport will be increased to 20 million tons per year then.

Another one is the line from Tayshet (Russia) to Nakhodka (Russia) with a branch line to Da-qing in China. The phase I of the project, from Tayshet to Skovorodino 60 kilometers north to the border with northeast China, will begin construction in summer 2006 and put into use by November 8, 2008, with an annual oil transmission capacity of 30 million tons. After it is completed, the branch line from to Nakhodka (Russia) to Da-qing (China) will first be constructed and put into use.

When these two pipelines are put into use, they will participate in the crude oil import of China and take part of the share that used to be taken by waterway transport.

3.3. Analysis of the Result of the Forecast

Next, the result coming from the quantitative forecast will be adjusted according to the qualitative analysis. The objective of the qualitative analysis is to make predictions of some factors of influence that are irregular or accidental. Considering the five factors discussed above, the adjustments is made and then added on the result of quantitative forecast. The final result is shown in Table 9 below.

Table 9: Quantitative Adjustments and Final Results of the Forecast

Unit: million tons

Year	Quantitative Forecast	Qualitative Adjustment	Final Result
2006	137.72	2	139.72
2007	149.47	3	152.47
2008	162.15	3	165.15
2009	175.86	2	177.86
2010	190.70	1	191.70
2011	206.80	5	211.80
2012	224.27	6	230.27
2013	243.27	2	245.27
2014	263.95	-1	262.95
2015	286.49	-3	283.49

4. STATUS QUO OF THE CRUDE OIL FLEET IN CHINA

4.1. Main Chinese Shipping Companies That Transporting Crude Oil

Generally, there are 4 shipping companies take the responsibility to the oil transportation in China. They are China Shipping Group Company, China Ocean Shipping (Group) Company, China Changjiang National Shipping (Group) Corporation and China Merchants Group. And there are some private enterprises set foot in the oil transportation industry such as Haichang Group Co., Ltd and Hebei Ocean Shipping Co., Ltd.

4.1.1. China Shipping Group Company

China Shipping Development Co., Ltd is a large shipping company held by China Shipping Group Company and listed in Hong Kong. In November 1994, company was successfully listed in Hong Kong exchange market and issued H-Share (1138). In May 2002, company issued 350 million additional new A-shares in Shanghai Stock Exchange (600026). China Shipping Development Co., Ltd Tanker Company is a professional shipping company which is a subsidiary company of China Shipping Development Co., Ltd. China Shipping Development Co., Ltd Tanker Company owns and manages 85 different types of tankers including VLCC, AFRAMAX, PANAMAX and HANDY-SIZE. The total deadweight tonnage of the fleet of the company is 2.52 million tons. China Shipping Development Co., Ltd

Tanker Company transports 60 million tons of oils per year and its asset is over 5 billion, which makes it the largest oil shipping company in China. Its headquarters is in Shanghai and there's a branch in Guangzhou.

China Shipping Development Co., Ltd Tanker Company has 50 years' experience in water way oil transportation. Its businesses are mainly domestic and overseas import/export oil transportation. The company is operated under ISM Code and comes out top in the safety inspection of famous international oil companies such as SHELL, BP, CHEVRON,EXXON and STATOIL and so on. In recent years, under the lead of the company's Board of Directors, the profit of the company is growing steadily and the performance is excellent.

In order to adapt to the development of national economics and the requirement of the strategic petroleum reserve systems of China, China Shipping Development Co., Ltd Tanker Company has set a strategic goal of "constructing a world class oil tanker fleet" and is implementing the plan to adjust the structure of the fleet in a big way. On 13th November 2003, the first 300 thousand tonnages VLCC of China Shipping Development Co., Ltd Tanker Company began construction. To 2010, company will own and manage a large multi-type oil tanker fleet comprised of VLCC, SUEZMAX, AFRAMAX, PANAMAX and HANDY-SIZE.

4.1.2. China Ocean Shipping (Group) Company

China Ocean Shipping (Group) Company (COSCO) is a large state owned company with shipping and modern logistics as the core business and doing businesses globally. Today, followed by more than 40 years of arduous efforts, COSCO has successfully molded itself into a global company with one of the most recognized

and admired brand name in the world. As far as the fleet capacity is concerned, we now own and operate a variety of merchant fleet of some 600 vessels with total carrying capacity of up to 35 million DWT, which help make a hit with achieving annual traffic volume of more than 300 million tons. In order to adapt to the development of national economics and the requirement of the strategic petroleum reserve systems of China, developing a first class tanker fleet is one of the strategic goals of COSCO.

Dalian Ocean Shipping Company (COSCODL) is a subsidiary company of COSCO who owns and operates the tanker fleet of COSCO and run the business of oil transportation for COSCO. COSCODL is developing an oil-tanker-focused liquid bulk fleet including oil tankers, liquefied gas carriers and chemical tankers. Today, the company has a 29-vessel fleet including 3 VLCC. The total deadweight tonnage of the tanker fleet of COSCODL is over 2 million tons. The fleet of COSCODL is one of the largest professional tanker fleet in China.

4.1.3. China Changjiang National Shipping (Group) Corporation (CSC)

CSC Nanjing Tanker Corporation, a subsidiary under "China Changjiang National Shipping (Group) Corporation" (CSC) is a shipping enterprise specialized in the shipping of oil and oil products. Established on Oct.1st, 1975, Nanjing Tanker Corporation of today possesses over 380 ships of various sizes, ranging from VLCC, AFRAMAX, PANAMAX, and MR size to small tankers, barges and tugs with a total deadweight tonnage of approx.1.5 million tons. Its trading area extended all over the globe, with an annual carriage volume of 41.60 million tons, among which over 20 million tons comes from seaborne trade, including costal business and deep seas. Its business scope has been developed from simply providing supplementary crude

oil transportation for petrochemical enterprises along the River to a large tanker enterprise with the capacity to transport six major types of cargos as crude oil, product oil, chemical products, liquefied petroleum gas, bitumen, and edible oil. Currently, the company possesses 28 oil tankers, totally of 1.01 million deadweight tons.

Nanjing Tanker Corporation is now concentrating its main resources and forces to reinforce the development of crude oil imported transportation, international clean oil transportation, and the special transportation of chemical products, LPG, bitumen etc., in order to construct a world-famous and national first-class large oil transport enterprise of international competitive ability. Till 2010, Nanjing Tanker Corporation will possess and control three major fleets. One is the VLCC fleet, of 8-10 VLCC carriers, and participates in China imported crude oil transportation.

4.1.4. China Merchants Group

China Merchants, with shipping as its traditional business, retains a significant place in the international shipping centre of Hong Kong. China Merchants is Hong Kong's second independent ship-owner and operates a commercial fleet 28 vessels of which oil tankers form a large proportion: 7 VLCCs of 280,000-300,000 DWT, 1 SUEZMAX tanker of 150,000 DWT, and 8 AFRAMAX tankers of 8-10 DWT, making China Merchants the ninth independent oil tanker owner in the world, and the largest operator of VLCC fleet of China. The total deadweight tonnage of the oil tanker fleet is approximately 3 million DWT. During 2003 and 2005, China Merchants Group invested and ordered a group of oil tankers of 1.5 million DWT. China Merchants Group provides high level crude oil transportation services to global oil companies and oil traders such as EXXON-MOBIL, SHELL and BP for a

long term, especially in Far East market.

Since 2003 China Merchants Group has signed strategic cooperation agreements on crude oil transportation with China Petroleum & Chemical Corporation and Sinochem Corporation. During the year 2004 to 2005, China Merchants transported over 10 million tons of imported crude oil for China (another 50 million tons for other countries in the world).

The oil tanker fleet of China Merchants Group is operated by Hong Kong Ming Wah Shipping Co., Ltd, a large shipping company founded and registered in Hong Kong in January 1980 as a company wholly-owned by China Merchants Group Limited.

4.1.5. Private Enterprises Set Foot in the Oil Transportation Industry

Haichang Group Co., Ltd started with oil trade in 1992. And till now with twelve years' development and expansion, it has become one of the most professional enterprises in Chinese ocean trade and shipping for its oil trade, oil shipping and shipping agent. Haichang Group has an oil tanker fleet that comprises three domestic oil tankers and two international ones. With a total carrying capacity of 26,500 tons, the 3 domestic oil tankers specialize in the fined oil shipping along the domestic coastland and the middle and lower reaches of the Yangtze River. Yearly capacity of them totals 70,000 tons. International ocean crude oil freight is mainly undertaken by the newly built VLCC and a tanker with a 15,000-ton-capacity. Shipping between such areas as the Middle East and South East Asia, the two vessels carry 2 million tons of oil every year. Another three VLCCs are under building and is scheduled to be weigh anchors within 3 years.

Hebei Ocean Shipping Co., Ltd (HOSCO), established in 1980, is mainly engaged in global ocean transportation. Ever since the beginning of 1998, the company has made great progress and outstanding achievements in its management, fleet growth and operation profit. To the end of 2005, HOSCO has owned a comprehensive fleet of 42 vessels amounting to a total deadweight tonnage of 5.12 million, which consists of PANAMAXes, CAPE SIZEs, VLCCs and a VLOC. With the vessels time-chartered, the total deadweight tonnage under operation of HOSCO is up to 10 million, carrying cargoes including grain, iron ore, fertilizer, coal, crude oil, etc.

Haichang Group Co., Ltd and Hebei Ocean Shipping Co., Ltd react very quickly and develop fast. However, since the imported crude oil of China is monopolized by some stated owned companies like China Petroleum & Chemical Corporation (SINOPEC), these private enterprises are unable to compete with those large shipping companies in the short-term. They can only play subordinate roles or even spectators in this market.

4.2. The Existing Fleet for Transporting Imported Crude Oil

The in being oil tankers for imported crude oil transport of the 5 companies are listed in Table 10. Presently, there are 18 PANAMAXes, 15 AFRAMAXes, 4 SUEZMAXes and 18 VLCCs available for ocean shipping. The total dead weight tonnage of all these tankers is about 8.5 million tons, most of which are VLCCs. However, these vessels serve not only for China, but other countries as well. For example, China Merchants Group transported 10 million tons of crude oil for China during 2004 – 2005, while 50 million tons for other countries.

Table 10: The Types and Number of Vessels That Involved in the Transportation of Imported Crude Oil of China

	PANAMAX	AFRAMAX	SUEZMAX	VLCC
China Shipping	8	6	0	2
COSCO	7	0	3	3
CSC	3	2	0	1
China Merchants	0	7	1	6
Haichang Group	0	0	0	1
HOSCO	0	0	0	5
Total	18	15	4	18

4.3. Main Routes for Crude Oil Import of China

China imports crude oil from many countries, and they are mainly in three regions: South East Asia, Middle East and West Africa. So presently, there are 3 main sea routes for China to import crude oil. (Peng Chu-ta, 2004, pp.25-26)

1. South East Asia - China

Loading at ports in South East Asia countries such as Malaysia and Indonesia, and then sail north via South China Sea, to discharge at the ports in the south area of China, or via South China Sea and Taiwan Strait, to discharge at the Ports in the north and east area of China.

2. Middle East - China

This route can be divided into two parts, one is from the Persian Gulf to China and the other one is from the Red Sea to China.

For the route from the Persian Gulf to China, vessels load at ports along the shore of

the Persian Gulf and sail through the Strait of Hormuz to the Gulf of Oman, then via the Arabian Sea into the Indian Ocean. After pass through Colombo, there are two lines can be chosen to sail. One is via the Lombok Strait and Selat Makassar Strait to the ports in China. The other one is via the Strait of Malacca to the ports in China. Since the depth of the Strait of Malacca is 21 meters, the largest ship that can pass the strait is 300,000 DWT VLCC with shallow draft. And the depth of the Lombok Strait is 30.5 meters, all types of oil carriers including VLCC can pass though it.

For the route from the Red Sea to China, vessels load at ports along the shore of the Red Sea and sail through the Bab el Mandeb Strait, via the Gulf of Aden and into the Indian Ocean. After pass through Colombo, there are two lines can be chosen to sail. One is via the Lombok Strait and Selat Makassar Strait to the ports in China. The other one is via the Strait of Malacca to the ports in China.

3. West Africa - China

There are two lines involving in this route.

One is sailing south and passing the Cape of Good Hope into the Indian Ocean. After pass through Colombo, there are two lines can be chosen to sail. One is via the Lombok Strait and Selat Makassar Strait to the ports in China. The other one is via the Strait of Malacca to the ports in China. Limited by the size of the Cape of Good Hope, the largest vessel that can sail in this route is the 150,000 DWT vessel.

The other is sailing north and passing the Suez Canal to enter the Red Sea. Then sail through the Bab el Mandeb Strait, via the Gulf of Aden and into the Indian Ocean. After pass through Colombo, there are two lines can be chosen to sail.

One is via the Lombok Strait and Selat Makassar Strait to the ports in China. The other one is via the Strait of Malacca to the ports in China. Restricted by the depth and width of the Suez Canal, the largest vessel that can pass the canal is SUEZMAX.

4.4. Problems of China's Crude Oil Import Situation

Among all crude oil imported, about 90% is transported by water; another 10% is by pipeline or other land mode of transportation. However, what worries us is that 90% of the waterway crude oil transport is undertaken by foreign tankers, which makes China's energy security out of control by China itself. Especially on the route West Africa – China and Middle East – China, Chinese shipping companies undertake little share of transport. Middle East has the most abundant crude oil reserves in the world. And West Africa is becoming more and more important in the crude oil export. These two areas are comparatively close to China than America, another crude oil abundant region. So China imports a large proportion of crude oil from Middle East and West Africa. It is reported that more than 70% of China's crude oil import is from these two areas. Once China meets with war, political sanction or some other forces majeure, the situation of energy shortage can be expected. It is dangerous for China. Nowadays, Chinese shipping companies only can afford to carry less than 10% of the waterway imported crude oil. But it is safe to carry at least 50% of oil by national fleet to guarantee the security of energy sources. (Chen Guo-xiong and Wei Chun-ling, 2005, pp.16-17) So it is necessary to research on the development of the fleet carrying imported crude oil.

5. FLEET DEPLOYMENT PLANNING

With the fast increasing of crude oil import of China, the capacity of the main Chinese enterprises that involved in the crude oil transportation is not enough obviously. Under such a situation, the transport of imported crude oil of China is mainly relied on foreign oil tankers. In chapter 3 of this paper, the relationship between economic growth and crude oil supply has been expounded. The sustainable economic growth of china requires a stable energy supply. However, if crude oil, the main energy resource used in China, is mainly relied on foreign oil tankers, the China's supply chain of energy will be out of control by China itself in the complex international situations and relationships. The security of the energy supply of China is threatened.

In order to ensure the stable growth of the economy of China, the government has decided to carry out the strategy of the security of national energy. Tanker fleet for carrying imported crude oil is planned to be developed. The direction in "Guideline of the Structure Adjustment of Chinese Waterway Transportation" published by the Ministry of Communications of the People's Republic of China is very clear: About the oil market, the development should be oriented by the market demand. The objective is to large-size and professionalizes the vessels and to develop a professional tanker fleet by adjusting the total capacity; optimizing the structure of the capacity and improving the technical level of vessels.

Based on the objective and direction of the Ministry of Communications of the People's Republic of China, the enterprises that involved in the crude oil transportation take actions positively. They revise their development strategies, adjust the structures of their fleets, speeding the construction of their fleets and hope to change the situation that the imported crude oil of China is transported mainly by foreign tankers as soon as possible.

In this chapter, on systematic thoughts, the scale and structure of the tanker fleet to satisfy the demand of crude oil import of China will be estimated.

5.1. Modeling for Fleet Deployment Planning

In this paper, a linear programming model will be applied to solve the problem of fleet deployment for carrying imported crude oil in China.

Before the model is established, some descriptions and assumptions to the problem should first be listed. (Xie Xin-lian, 2000, pp. 109-110)

1. There are several loading ports and discharging ports constituting several sea routes. Usually, oil tankers load crude oil full and down in the loading ports at one go and discharge the cargo at one go in the discharging ports. And then, the vessels back to the loading ports and prepare to load for another time.
2. The fleet contains several types of vessels operating in several sea routes.

3. The traffic on each sea route is certain and the fleet should accomplish the prearranged task of traffic.

4. The programming period is N, starting in year 0 and ending at the end of year N-1. The capital is settled once a year and cost of purchasing and operation arises at the beginning of each year.

5. The investment and cost arising before the programming period will not be considered in the model.

The problem to be solved is to deploy different types of vessels in several routes to complete the transportation of a certain amount of imported crude oil, with the reasonable purchase of new vessels within a certain period of time. The objective is to minimize the total cost of the fleet. So the programming model is established as shown below. (Xie Xin-lian, 2000, pp. 110-111)

Object Function:

$$\text{Min } Z = \sum_{t=0}^{N-1}(1+i_0)^{-t}\{\sum_{j=1}^{K}[\sum_{h=1}^{G} X_{jht}\cdot R_{jht} + O_{jt}\cdot F_{jt} + C_{jt}\cdot S_{jt}]\}$$

Constraints:

1. To accomplish the prearranged task of traffic:

$$\sum_{j=1}^{K} X_{jht}\cdot V_{jht} = W_{ht}$$

h = 1, 2, ... , G; t = 0, 1, … , N-1

2. To keep the consistency of the fleet development:

$$\sum_{h=1}^{G} X_{jht} + O_{jt} = A_j + \sum_{B=0}^{t}(C_{jB} - WT_{jB})$$

j = 1, 2, … , K; t = 0, 1, … , N-1

3. To ensure the variables to be non-negative:

$$X_{jht} \geq 0$$

$$O_{jt} \geq 0$$

$$C_{jt} \geq 0$$

j = 1, 2, … , K; h = 1, 2, ... , G; t = 0, 1, … , N-1

in which: Z is the object function which is the total cost in the programming period;

X_{jht} is a variable, which represents the number of type j vessel deployed on route h in year t;

O_{jt} is a variable, which represents the number of idle vessel of type j;

C_{jt} is a variable, which represents the new added type j vessel in year t;

R_{jht} is the operation cost of type j vessel on route h in year t;

F_{jt} is the annual idling cost of type j vessel in year t;

S_{jt} is the purchasing cost of type j vessel that come into operation in year t;

V_{jht} is the annual traffic of a single vessel of type j on the route h in year t;

W_{ht} is the prearranged traffic to complete on route h in year t;

A_j is the number of type j vessel at the beginning of the programming period (year 0);

WT_{jt} is the number of retired type j vessel in year t;

i_0 is discount rate that represents the time value of capital;

K is the total number of vessel types;

G is the total number of routes.

5.2. Parameter Computing

5.2.1. Programming Period

The programming period is from 2006 to 2015, so N = 10.

5.2.2. Number and Types of vessel

In fleet deployment planning, the main task is to make decision on the types and number of vessels. Presently, there are 6 companies involve in the imported crude oil transport of China, the types and number of these companies have been listed in the Table 10 already. Considering that only 1/6 of the transport capacity of China Merchants Group is served for China's crude oil import, I assume that there are 1 VLCC and 2 AFRAMAXes of the China Merchants fleet are used to transport imported crude oil for China. So the initial status of the fleet for Crude oil import of China can be obtained. (See Table 11)

Table 11: The Types and Number of Vessels That Involved in the Transportation of Imported Crude Oil of China at the Beginning of the Programming Period

Type	PANAMAX	AFRAMAX	SUEZMAX	VLCC
Number	18	10	3	13

According to the collected materials, considering the new building plans and the ages of the in being vessels of the main shipping companies, Table 12 shows the change of

the number of vessels in the next 10 years.

Table 12: The New Building and Retirement Plan (2006 – 2015)

	New Building Plan			
	PANAMAX	AFRAMAX	SUEZMAX	VLCC
2006				2
2007				4
2008				
2009				4
2010				
2011				
2012				
2013				
2014				
2015				
	Retirement Plan			
	PANAMAX	AFRAMAX	SUEZMAX	VLCC
2006				
2007				
2008				
2009				
2010	-2			
2011				
2012	-2	-7		
2013				
2014				
2015				

5.2.3. Sea Routes for China's Crude Oil Import

China imports crude oil mainly from Middle East, West Africa and South East Asia. It is reported that about 90% of the imported crude oil is from these three areas and the rest 10% is mainly transported by pipeline from Former Soviet Union countries.

These years, South East Asia exports crude oil less and less since the economy of South East countries is growing and they need more and more oil. The terrorism and political instability of Middle East makes China import less crude oil from Middle East. As a result, China imports more crude oil from West Africa. However, in the long run, Middle East is still the main source for China to import crude oil.

There are many routes for crude oil import of China. For the purpose of convenience in programming, in this paper, the loading ports and discharging ports of China's crude oil import will be combined into several main region according to the degree of centrality. And some small ports will be merged into the nearest main regions. Thus, the sea routes for crude oil import of China can be reduced.

1. In South East area, China imports crude oil mainly from Indonesia and Malaysia. For other South East countries, China imports only a little crude oil. The oil ports of Indonesia and Malaysia locate very close and the loading and discharging condition and port charges of their oil ports is also very similar. So the oil ports in this area can be merged into one, here we use South Asia ports to represent these oil ports in Indonesia and Malaysia.

2. In the Persian Gulf and the Red Sea areas, oil ports are situated closely. Oman is a country near the Persian Gulf area; the ports in Oman are not inside the Persian Gulf. They are on the shore of the Gulf of Oman and the Arabian Sea. Yemen located in the Red Sea area, its oil ports are in the Gulf of Aden. Vessels don't need to pass the Bab el Mandeb Strait to loading crude oil from Yemen. The oil ports in Saudi Arabia are distributed along the shore of the Red Sea and the Persian Gulf. Comparing with the distance between China and Middle East Area,

the distance among these Middle East ports are not long. So here we use Middle East ports to represent these ports in the Red Sea area and the Persian Gulf area.

3. In West Africa, China imports crude oil mainly from Nigeria, Congo and Angola etc. The oil ports in these countries are mainly located in the Gulf of Guinea area and nearby areas. So we use West Africa ports to represent these oil ports.

4. For the discharging ports in China, they are mainly distributed in 3 areas. They are Bo-hai Gulf area, Yangtze River Delta and Pearl River Delta. For the convenience of computing, we consider them all as one port, which is China.

By the classification above, 3 sea routes for crude oil import of China can be summarized. (See Table 13)

Table 13: Sea Routes for Crude Oil Import of China

Route 1	Route 2	Route 3
South Asia - China	Middle East - China	Africa - China

5.2.4. Prearranged Annual Traffic and Annual Capacity of Single Vessel

Nowadays, China imports crude oil mainly from 3 areas. Their shares are shown in the Table 14. 20% of the imported crude oil is from South East Asia; 50% is from Middle East and 20 % is from Africa. The rest 10% of imported crude oil is transported by land mode. In the future, the structure of crude oil import sources of China will change.

Table 14: Structure of China's Crude Oil Import Sources at Present

Route 1	Route 2	Route 3	Others
South Asia - China	Middle East - China	Africa - China	Non-Waterway
20%	50%	20%	10%

Middle East keeps the main supplier of global petroleum for a long time. It is forecasted that till 2020, production of petroleum in Middle East will take up 40% of the world's production. In 2001, 2002, 2003 and 2004, about 56%, 50%, 51% and 45% of Chinese imported crude oil are from Middle East. It's forecasted by IEA that in 2020, the production of crude oil in Middle East will reach 2200 million tons, among which, about 400 million tons are locally needed. Then about 1800 million tons of crude oil will be supplied to other districts. It is predicted that up to 2010 and 2020, still 45% to 50% crude oil which is imported by China will come from Middle East. The condition of China's dependency on crude oil from Middle East won't change much.

The quantity of Crude oil from Asia-Pacific Region will decrease continuously. In 2000, 2001 and 2002, 15%, 14% and 17% of crude oil were from Asia-Pacific region. It's anticipated by IEA that by the year 2020, production of crude oil in Asia-Pacific region is 435 million tons, while the consumption is 1610 million tons. The quotient of crude oil imported from Asia-Pacific region by China will be reduced continuously. It's estimated that the proportion of crude oil imported from the region will reduced to less than 10% from 15% at present.

The proportion of crude oil import from Africa will be kept. It is predicted by IEA that by 2020, production of crude oil in Africa will reach 575 million tons, and in 2020, the quantity of crude oil in Africa which can be exported will be 475 million

tons. In the year 2000, 2001 and 2002, the quotient of crude oil imported from Africa was 24%, 22% and 23%. It's estimated that in 2020 in China, the crude oil imported from Africa will be 25%.

Russia and Caspian-Sea area will be the key crude oil importing areas in future. We try to import 20% to 25% more of crude oil from these areas. Central Asia-Caspian-Sea area is a main production area of petroleum also. Its' anticipated that in the 2015, the production of petroleum in Kazakstan in Central Asia and Azerbaijan will be up to 150 million tons, most of which will be used for exporting. As for China, we should press on with the reinvestment work of crude oil pipelines between China and Kazakstan to shoot for gaining crude oil in Kazakstan. In this way, up to 2020, we can import up to 50 million tons of crude oil from former Soviet Union countries.

Therefore, by 2015, the structure of China's crude oil import sources is supposed to be: 50% from Middle East, 25% from Africa, 10% from Asia-Pacific and 15% to from Russia and Central Asia by land mode of transportation. (See Table 15)
Here I assume that Chinese tankers will be able to carry 51% of the waterway imported crude oil in 2015 from 15% in 2006. Combining the data in Table 4.5 and Table 2.7, prearranged annual traffic can be obtained. (See Table 16)

Table 15: Future Structure of China's Crude Oil Import Sources

Route 1	Route 2	Route 3	Others
South Asia - China	Middle East - China	Africa - China	Non-Waterway
10%	50%	25%	15%

Table 16: Prearranged Annual Traffic Unit: million tons

Traffic	Route 1 10%	Route 2 50%	Route 3 25%	Subtotal	Total Waterway Imports	Share
2006	1.78	8.91	4.45	15.14	118.76	15%
2007	2.46	12.31	6.16	20.93	129.60	19%
2008	3.23	16.14	8.07	27.44	140.38	23%
2009	4.08	20.41	10.20	34.70	151.18	27%
2010	5.05	25.26	12.63	42.94	162.95	31%
2011	6.30	31.51	15.75	53.56	180.03	35%
2012	7.63	38.17	19.08	64.88	195.73	39%
2013	8.96	44.82	22.41	76.20	208.48	43%
2014	10.50	52.52	26.26	89.29	223.51	47%
2015	12.29	61.45	30.72	104.46	240.97	51%

Next, annual capacity of single vessel of each type in each route should be estimated. For the convenience of computing, I assume that each type of vessel has the same DWT. PANAMAX is 68,000 DWT; AFRAMAX is 95,000 DWT; SUEZMAX is 140,000 DWT and VLCC is 280,000 DWT. Considering the DWT of each type of vessel and the distance of the 3 routes for crude oil import of China, Table 17 listed the estimated annual capacity of single vessel of each type in each route.

Table 17: Annual Capacity of Single Vessel Unit: million tons

	Route 1	Route 2	Route 3
PANAMAX	1.02	——	——
AFRAMAX	1.43	0.7125	0.475
SUEZMAX	——	1.05	0.7
VLCC	——	2.10	1.4

5.2.5. New-building Price

Table 18 shows the recent prices of new-building vessels. For the convenience of

computing, here I assume that the new-building price does not change in the programming period.

Table 18: New-building Price Unit: million USD

	PANAMAX	AFRAMAX	SUEZMAX	VLCC
N. Bld. Price	50	60	70	105

Source: Maritime Information

5.2.6. Operation Cost of Different Types of Vessels

The operation cost of a vessel is consisted of 3 parts: capital cost, voyage cost and daily cost. Capital cost includes depreciation cost and interests. Voyage cost includes fuel oil cost and port charges etc. Daily cost includes the cost of repair, insurance, wages, spare parts, lubricate oil and administration cost etc. And idling cost is the cost when a vessel is not in operation.

Table 19: Annual Operation Cost Unit: million USD

	Route 1	Route 2	Route 3	Idling Cost
PANAMAX	10.22	——	——	1.65
AFRAMAX	11.31	11.31	11.35	1.85
SUEZMAX	——	13.15	13.29	2.08
VLCC	——	18.30	18.64	2.90

According to the data collected, annual operation cost and idling cost are estimated. (See Table 19) Here I use the recent average bunker price of 350 USD per ton. For the convenience of programming, here I assume that the operation cost and idling cost do not change in the programming period.

5.3. Linear Programming of Fleet Deployment Planning

By using the 'solver' function of Microsoft Excel, combining the data obtained above with the Objective function shown in 4.2, the model can be established. (See Figure 12)

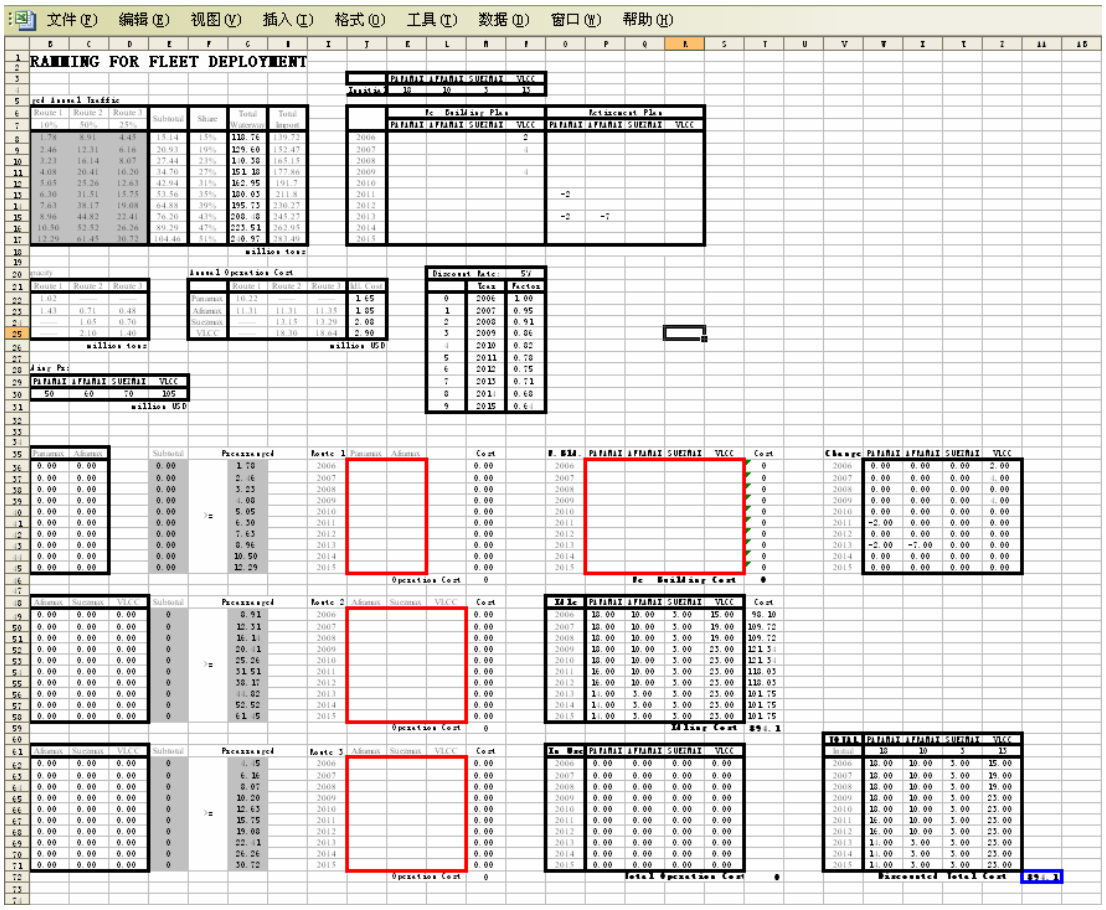

Figure 12: Modeling of Programming by Excel

After defining the objective function, variables and constraints (See Figure 13), the result is obtained. The optimized operation cost is 6339.71 million USD. At the same time, the development of the scale of the whole fleet from 2006 to 2015 and the optimal deployment of the fleet is obtained automatically.

Figure 13: The Input of Objective Function, Variables and Constraints

Table 20: The Development of the Fleet for China's Crude Oil Import

	PANAMAX	AFRAMAX	SUEZMAX	VLCC
Initial	18	10	3	13
2006	18.00	10.00	3.00	15.00
2007	18.00	10.00	3.00	19.00
2008	18.00	10.00	3.00	19.00
2009	18.00	10.00	3.00	23.00
2010	18.00	10.00	3.00	23.00
2011	16.00	10.00	3.00	25.00
2012	16.00	10.00	3.00	31.00
2013	14.00	3.00	3.00	37.00
2014	14.00	3.00	3.00	43.00
2015	14.00	3.00	3.00	49.00

Table 20 shows the optimized development of fleet scale for crude oil import of China. Up to 2015, 14 PANAMAXes, 3 AFRAMAXes, 3 SUEZMAXes and 49 VLCCs will be needed to transport 51% of the waterway imported crude oil for China. We can see that VLCC is the most needed type of vessel to import crude oil for China. All the new building vessels are of VLCC type. This Phenomenon is result from the structure of China's crude oil import sources. Because West Africa

and Middle East, the 2 main sources of crude oil supply, are far from China, for the consideration of economic effective, large vessel is the best choice.

Table 21 is the optimized deployment of each type of vessel in each route from 2006 to 2015. In route 1 (South Asia - China), before 2012, vessels of AFRAMAX type will be used to transport imported crude oil; after 2012, PANAMAXes will gradually substitute for AFRAMAXes. In route 2 (Middle East - China), all the transport will be undertaken by vessels of VLCC type. In route 3 (Africa - China), VLCCs are the main force, which are assisted by PANAMAXes and AFRAMAXes. By such arrangement, the total operation cost can be optimized.

Table 21: Optimized Deployment of the Fleet

	Route 1		Route 2			Route 3		
	PANA.	AFRA.	AFRA.	SUEZ.	VLCC	AFRA.	SUEZ.	VLCC
2006	0.00	1.25	0.00	0.00	4.24	0.00	0.00	3.18
2007	0.00	1.72	0.00	0.00	5.86	0.00	0.00	4.40
2008	0.00	2.26	0.00	0.00	7.69	0.00	0.00	5.77
2009	0.00	2.85	0.00	0.00	9.72	0.00	0.00	7.29
2010	0.00	3.53	0.00	0.00	12.03	0.00	0.00	9.02
2011	0.00	4.41	0.00	0.00	15.00	0.00	2.51	10.00
2012	0.00	5.34	0.00	0.00	18.17	0.00	1.61	12.83
2013	4.58	3.00	0.00	0.00	21.34	0.00	0.71	15.66
2014	6.09	3.00	0.00	0.00	25.01	0.00	1.54	17.99
2015	10.76	0.92	0.00	0.00	29.26	2.08	3.00	19.74

And Table 22 is the number of idle vessels in each year from 2006 to 2015. With the increase of crude oil import of China, the idle vessels in the fleet will be less and less. Up to 2015, only 3.24 PANAMAXes are to be idled. These idle vessels listed in Table 22 can be used to serve for other countries to make full use of them.

Table 22: Number of Idle Vessels

	PANAMAX	AFRAMAX	SUEZMAX	VLCC
2006	18.00	8.75	3.00	7.58
2007	18.00	8.28	3.00	8.74
2008	18.00	7.74	3.00	5.55
2009	18.00	7.15	3.00	5.99
2010	18.00	6.47	3.00	1.95
2011	16.00	5.59	0.49	0.00
2012	16.00	4.66	1.39	0.00
2013	9.42	0.00	2.29	0.00
2014	7.91	0.00	1.46	0.00
2015	3.24	0.00	0.00	0.00

5.4. Analysis of the Programming Result

Although linear programming model is a mature technique of fleet deployment planning, its drawbacks still exist. Since the environment is complex, it is difficult to consider all the factors in one model, otherwise it will be impossible to solve. To make the model truthful as well as convenient to compute, some assumptions are necessary. As the assumptions omitted many factors of influence, the model is a theoretical one for reference. Firstly, in this model, routes are combined and summarized into 3 ones, thus the distance differences are omitted. The conditions of many neglected loading ports and discharging ports may affect the result in real practice. Secondly, customer's requirement is another factor of influence. Practically, some customers may require that a certain type of vessel should be used to transport the oil he purchased. And the amount of cargo may not be full and down and the annual traffic will be affected. These factors will make the real arrangement different from that coming from this model. Thirdly, these vessels are operated under certain companies and they usually served not only for crude oil

import of China. They may also serve internationally for other customers. Therefore, the routing mode will not be simply end-to-end, but possibly triangle as well. This factor is not considered in this model. Fourthly, only new building ships is considered in this model but other ways of obtain vessels are not. Actually, purchasing second-hand ships and leasing ships are also a good method to obtain new transport capacity. And additionally, because of the limitation of available data and materials, some figures are estimated and errors may exist.

Although there are errors in this model and its result, they are not that big and unacceptable. To make a more accurate programming for the deployment of fleet for China's crude oil import, these factors should be considered as well.

6. PROBLEMS TO CONSIDER WHEN DEVELOPING THE FLEET FOR CRUDE OIL IMPORT OF CHINA

With the expanding of China's oil tanker fleet, some problems are inevitably to be encountered.

6.1. The Security of the Sea Routes for Crude Oil Import of China

It has been a fact and trend that China depends more and more on the international supply of crude oil. Since China became a net importer of crude oil in 1993, with 10 years' development, China has been the second crude oil consumer of the world. In 2005, China imported 126.82 million tons of crude oil and more than 90% of the imported crude oil is transported by water. So how to keep the security of the channel for crude oil import of China becomes a problem.

Presently, China imports crude oil most from Middle East and West Africa, so it has become strategically important for some key paths in the routes such as the Strait of Malacca, the Strait of Hormuz and the Cape of Good Hope and so on. However, China only has very limited control of these areas on the sea.

Let's take the Strait of Malacca as an example. Among all the imported crude oil of China more than 70% is from Middle East and West Africa, and another 10% from Europe. Importing crude oil from these regions, the Strait of Malacca is an

inevitable place in the sea route. That means, about 80% of the crude oil import of China must pass the Strait of Malacca. It is counted that nearly 60% of the daily traffic passing the Strait of Malacca is Chinese vessels. (Zhang Bang-song, 2004) It is undoubted that the Strait of Malacca has been closely bounded up with the security of China's economy. The Strait of Malacca which is dominated by Singapore, Malaysia and Indonesia together, located in a strategically important position as it influence the energy supply channel of the East Asia countries including China, Japan and Korea.

There are many unstable factors in the energy supply channel from Middle East to East Asia. Besides the political turmoil and terrorism in Middle East, the rampancy of piracy in the Strait of Malacca is another dangerous threat to the security of the energy supply channel. For the reason of striking the piracies, the navy of America, Japan and India and some other relevant South East Asia countries are arranged there. However, the connotation of such actions is clear, that is, to take precautions against the possible international conflicts. To China, piracy is not the only problem in the Strait of Malacca. A more serious problem is that the Strait of Malacca is a place where can cut the crude oil supply of China. The importance of the Strait of Malacca is obvious.

Ren Hai-ping, the director of the International Strategy Office of the Institute of Economics and Politics under the Chinese Academy of Social Sciences, said that the way of the energy supply channel from Middle East and West Africa to China almost all controlled by the potential competitors of China. It's OK if no accident happens, otherwise it will be a big trouble for China. And in many scholars' opinion, China worry about the embargo imposed on China by America more than the piracies. As America has been maintaining to push the Limit Policy against China for a long time,

it is possible for America to impose embargo on China when some accidents happens, such as the impossible military conflict between China and Chinese Taiwan. Once the conflict erupted, America will interfere and perform the naval blockade against the energy supply channel of China. For the feeling of insecurity about the energy supply, common people generally think that China should enhance the strength of the navy to contend with America. But such an action is not shown in the government's policy. And in scholars' opinion, no matter how powerful the Chinese navy is, it is not able to mention in the same breath with the navy of America. A more rational action is that to remove such kind of worry, China should communicate more with the governments of these countries to eliminate the misapprehend, not only in the technical level but in political and strategical level as well. At the same time, economic cooperation with Asia countries should be further strengthened. With the increase of interdependency, the possibility of embargo imposed by these countries will be decreased. (Zha Dao-jiong, 2005, pp. 3-4)

6.2. The Handling Capacity of Crude Oil Terminals in China

Nowadays, the crude oil handling capacity of the coastal ports in China is more or less match with the requirement. But with the increase of crude oil import of China, the burden on the port infrastructures will become increasingly heavy. If the handling capacity is not enough, the imported crude oil will not be efficiently discharged and transported to where it is needed. It is estimated that a more 80 million tons crude oil handling capacity is needed to meet the demand in 2010. To satisfy the increasing demand of crude oil import, constructing new crude oil terminals or expanding the handling capacity of in being ports is quite necessary, especially the construction of deep-water ports and deep-water channels that can accept 200,000 – 300,000 DWT VLCCs, as these kinds of vessels will be the main

force of imported crude oil transport in China.

According to the location of oil refineries and the demand distribution in China, the discharging ports of imported crude oil in China can be divided into 5 groups geographically. First is Bo-hai Gulf ports, in which Da-lian, Tian-jing and Qing-dao are the 3 leading ports to be developed. Second is Yangtze River Delta ports, in which dominated by Ning-bo port, Zhou-shan port and Shanghai port. Third is south east China ports leaded by Quan-zhou port. Fourth is Pearl River Delta ports dominated by Hui-zhou, Sheng-zheng and Zhu-hai ports. Last is south west China ports in which Zhan-jiang, Hai-kou and ports along Guang-xi Province are the leading ports.

In the next few years, these oil ports should be reconstructed and developed to meet the increasing demand for handling capacities.

6.3. Seafarer Resources of China

With the expansion of the oil tanker fleet, the demand for qualified and professional seafarers increases correspondingly. For the tankers that transport strategic resources like crude oil, the requirement for the crew is extremely high. However, the quantity and quality of Chinese seafarer resources is limited, especially those experienced officers for ocean shipping. To increase the quantity and raise the quality of Chinese seafarer resources, navigational education, sailor's training and seafarer's cultivation of higher quality are important and inevitable.

China has abundant maritime educational resources such as maritime universities, technological academies and vocational schools. To be a qualified seafarer or

officer who is urgently needed under the present situation, high level of education is necessary. Presently, the main sources of Chinese ocean shipping seafarers are not the graduates from domestic maritime universities of 4-year course of study. According to the employment situation of the graduates in recent years, over 50% of the graduates are not willing to work on board. Even they choose to work on board as their first job, many of them intend to exit this vocation in a few years. There are only less than 20% of the graduates want to take the vocation of seafarer as their lifetime profession in deed. (Gu Jian-wen, 2005, p. 35) Addition with the retirement of large number of old seafarers, the shortage of the supply of young seafarers will have impact on the balance and stability of maritime vocation. It is hard to increase the quantity of Chinese high quality seafarers when such a serious waste of maritime education resources exits.

Because of the policy of family planning of China, most of the graduates are the only children in their family. With the improvement of the standard of living, parents don't want their children to be engaged in such a vocation that will make children separate from the family for long time and children themselves are not willing to do such kind of job either. Additionally, comparing the income level of Chinese seafarers with that in the international market, Chinese seafarers earn less than the average level in developed countries though the wages of Chinese seafarers rising gradually these years. It gives a company the advantage of cost by hiring Chinese seafarers. However, it is also one of the main barriers that hinder people from join into the vocation of seafarers. Many of the graduates don't choose seafarers as their profession as they don't think that the income level is attractive to them.

There are many sailors' training centers in China, but little of them can provide high quality training services to improve the ability of seafarers. Most of them only

provide the service to train seafarers to better perform the contract. To cultivate a qualified and powerful seafarer is a systematic mission. Besides navigational education and sailor's training, exercitation and employment are important too. But in China, these two points are not well performed. Many shipping companies don't intend to pay much attention to the cultivation of seafarers; they are more willing to cultivate them by abroad-sending. So green-hands usually have little chance to practice their skills. And due to the China's policy that foreign companies can't hire Chinese seafarers directly from China, the seafarer's market is not a fully opened market. It is not good for the cultivation of Chinese seafarers.

To solve the problem of seafarer's shortage in China, opening and reform is the best solution. Seafarer is an international profession, so the education and training of seafarers should be connected with the global world. Apprentices should be sent abroad to make use of the advanced and developed educational resources outside China. Foreign education and training organizations should be invited to China to participate in the cultivation of Chinese seafarers. The income level of Chinese seafarers should be raised duly to stimulate the positivities of new graduates to be engaged in this profession. And for government, the policy should be changed to open the Chinese seafarer's market, letting Chinese seafarers have more opportunities to work internationally. Practice is the best way to improve skill level and gain experience. Through the practice, seafarers will be more competent for dealing with emergencies. Thus, the quantity and quality of Chinese seafarers can be improved gradually.

6.4. Anti-Pollution

With the development of China's economy, China imports more and more crude oil

by water. The crude oil throughput of ports is increasing year by year. At the same time, the hidden threat of pollution by oil spill is rising as well.

It is reported that from 1973 to 2003, there happened 2,353 oil spill accidents in the Chinese coastal areas, once each 3.5 days averagely. For those serious oil spill accidents of which the spilled oil is more than 50 tons, there happened 62 during the period of 1973-2003, with a total spilled quantity of 34,189 tons. These years, serious oil spill accidents happened frequently. On November 23, 2002, Maltese vessel "TASMANSEA" collided with Chinese vessel "SHUN KAI 1" in Tian-Jin sea area, 200 tons of crude oil was spilled into the water. On August 5, 2003, in the water resource protection sector of Huang-Pu River, an oil spill accident was happened of which 85 tons of fuel oil spilled in the river and seriously polluted 8 kilometers of water area, shoal and bank. On December 7, 2004, Panamanian vessel "HYUNDAIADVANCE" and German vessel "MSC ILONA" collided in the Pearl sea area, and made the latter one spill 1,200 tons of fuel oil. On April 3, 2005, Portuguese tanker "ARTEAGA", which carried 119,574 tons of crude oil, struck on rocks in the Da-Lian sea area, the third cabin on the starboard was damaged and the water nearby was polluted by the spilled oil. Some of these accidents were caused by oil tankers, and some were caused by other types of vessels. The influence of Oil spill pollution to the sea will last for long. It not only harms the environment and ocean resources, but results in serious economic losses and jeopardizes the human health. Additionally, the cost spent on cleaning the spilled oil is very large, and it is difficult for victims to claim for compensation.

Information shows that: the economic loss and the cleaning cost of the "The Exxon Valdez" accident in 1989 were as high as 8 billion US dollars. The Russian tanker "NAKHODKA" spilled oil in Japanese sea area caused a loss of 27 billion Japanese

Yen including the cost of cleaning. In 1995, the tanker “Tan Jia” hit the dock and resulted in the oil spilled into the water, which caused serious economic and environmental loss. All the countries in the world pay high attention to the oil spill accidents and oil pollution events.

On February 28, 1996, the “An Fu” tanker under the Fu-jian Shipping Company spilled 632 tons of crude oil into the sea due to the damage of hull. It is the most serious pollution accident happened in Fu-jian Province which caused a direct economic loss of 28.7 million RMB and fisher folks reported a loss of 0.13 billion RMB. The government of Fu-jian Province charged Fu-jian Shipping Company 3 million RMB as the compensation but fisherfolks set their face against it. And they lodged a civil action to the Maritime Court of Xia-men. The case was not settled until 5 years later in 2001, under the attention of related department of our country, an agreement was achieved that the trouble maker Fu-jian Shipping Company should pay 5.5 million RMB as compensation. However, the loss of victims and the environment is much more than the compensation.

Since the harmfulness of oil spill accidents is so serious, how to prevent, control and deal with oil spill accidents becomes more and more important for China to study for the protection of environment and ocean resources as well as for the development of economy.

In developed countries, to prevent and control the accidents, substandard vessels usually are not allowed to enter the sea area of the countries. And for domestic vessels, too old vessels will be forced to retire. Thus, the threats of accident can be limited. And when accident happens, a mature compensation system of oil pollution damages can guarantee the fair settlement of the case. Most of the

countries in the world are the members of the 1992 Civil Liability Convention and the 1992 Fund Convention. Some countries have domestic legislations to regulate the oil pollution compensation such as the Oil Pollution Act of 1990 of USA. And the compulsory insurance system makes the compensation easier to obtain.

But in China, the legislation is weak in oil pollution sector. Some substandard vessels which are not allowed to enter the ports of developed countries can enter the ports in China. Many small private oil transport companies purchase old second-hand tankers that have retired in foreign countries to operate. Once accident happens, ship-owner left the vessel and escape, leaving the cleaning and salvages work to the government and related department. Regarding the oil pollution compensation system, China is not the member of the 1992 Fund Convention, and the 1992 Civil Liability Convention can only be applied in Hong Kong of China. And there haven't got any special domestic legislations regulate the compensation of oil pollution. As a large oil importing country in the world, the threat of oil pollution is becoming larger and larger, China's ability to handle oil pollution cases need to improve urgently. To better the prevention and handling of oil pollution, next 4 points are important.

Firstly, build and promoting environment friendly tankers and improve the management of vessels. Double-hull tanker can effectively prevent the oil spill when collision or grounding is happened. IMO regulated that the in being single-hull tankers should be gradually quit the market. Because old vessel is more likely to cause accident, those vessels over a certain age should be forced to scrap. Although China has this kind of regulations, but the standard is a little bit low. For the safe of the environment, the standard should be raised. Secondly, standardize the on-board and loading / discharging operations to minimize the man-made

mistakes. Many accidents are happened because of man-made mistakes. Better training and standardization can eliminate the errors. Thirdly, develop emergency plan for oil pollution accidents. To quickly deal with the happened accident, preventing the pollution to diffuse, an emergency plan is necessary. Professional oil pollution cleaning teams should be built up and equipped with high-tech equipments. Fourthly, develop compensation systems of oil pollution damages. There are two ways to develop the system. One is enter the international conventions. The 1992 Civil Liability Convention and the 1992 Fund Convention constitute a mature system of compensation for oil pollutions. Directly enter into this system is one of the choices. Another one is to legislate domestically. Considering the domestic situation, China can create a new regulation to restrict the liability and compensation mechanism. It is more agile than the first way as it can take advantage of the international conventions and combine with the national condition of China.

7. SUMMARY AND CONCLUSION

With the development of China's economy, energy resources are increasingly needed for industrial use as well as civil use. Without sufficient energy resources, the economy will be unable to develop. Thus, the security of energy resources is becoming more and more important at the same time. Crude oil, as the main energy resource in use around the world, is no doubt a strategic material not only in economic consideration but political and military as well. A large proportion of China's crude oil consumption depends on import and the import of crude oil of China is increasing year by year. However, the situation of China's crude oil security is not that good. One of the main reasons is that China hasn't got a large enough tanker fleet for carrying imported crude oil.

From the analysis of world crude oil market, we can see that the most oil abundant areas are Middle East, Europe & Eurasia, Africa and S. & Cent. America. In which Middle East, Africa and S. & Cent. America are three areas which consume little but produce much. Considering the distances between these three areas and China, Middle East and Africa are better for China to import crude oil from than S. & Cent. America. So Middle East and Africa will be the main sources of China's waterway crude oil import. And according to the historical data, the future demand for imported crude oil is predicted in Chapter 3. Up to 2015, it is forecasted that 283.49 million tons of crude oil will be imported from outside China.

Nowadays, there are several shipping companies of China are involved in the business transportation of China's imported crude oil. Although they have their own fleet for crude oil transport, the scale of the fleet is too small to guarantee the security of energy resources. Therefore, China's tanker fleet for crude oil transportation should be carefully programmed to develop rationally.

According to the sources of China's crude oil import, it is estimated that about 75% of the demand will come from long distant area such as Middle East and Africa in the future. This determines that large size vessels are the main force for transport imported crude oil of China. And in order to accomplish the prearranged amount of import, after the linear programming computing, the result shows that 49 VLCCs and some other types of vessels are needed to guarantee the security of China's crude oil supply. By linear programming, the optimized deployment of the fleet is also educed. However, they are only theoretical solutions. In practice, the development of fleet also depends on the building capacity of the shipyards and the capital affordability of Chinese shipping companies. There also have many factors that will influence the development of fleet and the security of China's security of energy resources. For example, the security of sea routes, the handling capacity of China's oil terminals, Seafarer resources and anti-pollution problems. To build a competent fleet for China's crude oil import, these problems can not be ignored.

To sum up, in the aspect of the development of tanker fleet, China still has a long way to go.

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