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XIANGYU CAI

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KAPOSVÁR UNIVERSITY
FACULTY OF MANAGEMENT AND ORGANIZATIONAL
SCIENCES

Head of Doctoral School

Prof. SÁNDOR KERÉKES DSc

Correspondent Member of the Hungarian Academy of Sciences

Supervisor

Dr. ARNOLD CSONKA

Associate professor

EVALUATION OF STRATEGIC COST DRIVERS IN
THE CHINESE PETROLEUM SECTOR

Written by

XIANGYU CAI

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1. Introduction

How to strengthen the financial management and improve the level of administration to help a business grow, develop and make profit is a big issue in business management. With the development of the economy, enterprises start to focus on their level of cost management. In this increasingly competitive era, every enterprise wants to know how to maximize their benefits, they want to control their cost and do more things with the least money which is one of the ways to be successful. Cost management is one of the most important parts of business management. In today's society, cost management is critical to sustainable development of an enterprise, therefore, discussing the function and role of cost management in the field of business management becomes a popular topic.

Generally speaking, cost management is not an emerging field which existed as early as the period of rise industrial economy in 19th century (J. Wang, 2002). With the completion of the first industrial revolution, the socialization of larger-scale production has become an inevitable trend of economic development. Then the emergence and development of modern enterprises with certain scale led the role of cost management become more and more important. From the emergence of Taylorism in early 20th century to today's complex management theories and methods applied in multinational enterprises, science of management has gone through a long way for decades. In the development of management science, there is a trend that enterprises pay more and more attention to cost management. The reason why cost management is important is easy to understand. With the condition of market economy, the main purpose of

enterprise is to earn profit and profit acquisition is achieved after the cost of compensation. In the premise of certain market demand, reduce costs become the only way to pursue the maximal profit.

Cost management as an important part of business management, the main function and role is to provide accurate cost information for administrations to make decision (S. Wu, 2003). Since 1990s, with global economic integration and rapid development of high-tech, the internal and external environment changed tremendously. In order to cope with resource shortage and increasingly fierce competition, the traditional cost management needs to reform adaptively that strategic cost management has become the inevitable choice of enterprise to maintain long-term competitive advantage.

After two hundred years of development in management science, cost management in western countries formed a set of scientific and effective theories and methods. From product manufacturing cost to product life cycle cost, cost reduction to cost avoidance, production-based cost management to market-based cost management. All these theories and methods adapted to the internal and external changes of enterprises and provided enough information for the decision making of enterprises.

China's cost management learned and accumulated valuable experience after more than sixty years of development. It formed some methods such as team accounting, cost centralized management, cost accounting and market-oriented cost management etc. (X. Yu, 1999). After China became a member of the World Trade Organization in 2001, China's economy become more and more open, in the meantime business competition became much fiercer than ever.

With the expansion of market access and reduction of tariffs, more and more multinational enterprises came into Chinese market so that foreign products, services and investment swarm into the market compete with Chinese products and services. The traditional cost management model in China is not adapted to the economic development any more. These changes formed a complex internal and external environment of competition for Chinese enterprises, under this condition, Chinese enterprises need to learn and implement new methods of management to improve the competitiveness of enterprises so that enterprises can survive from fierce competition.

Petroleum is a product with character of commerce and national strategy (D. Chen, Wang, & Guo, 2009). The petroleum industry became international due to the regional differences in petroleum resources which are not renewable. The rapid development of world economic globalization has accelerated the pace of international petroleum industry in the world. Researches have shown that energy consumption of a country can boost GDP in the country and its growth rate is proportional to the growth rate of the national economy (Afgan, Gobaisi, & Carvalho, 1998). Petroleum and gas consumption accounted for more than 70% of primary consumption in developed countries (Z. Zhou & Tang, 2003). In China, petroleum and gas consumption only accounted for 25% of primary consumption, but the proportion continues to grow in recent years and petroleum and gas resources have become the main part of energy consumption which determines the direction of China's energy. It can be said that petroleum and gas resources are the basement of national sustainable development which also reflect comprehensive national strength of a country.

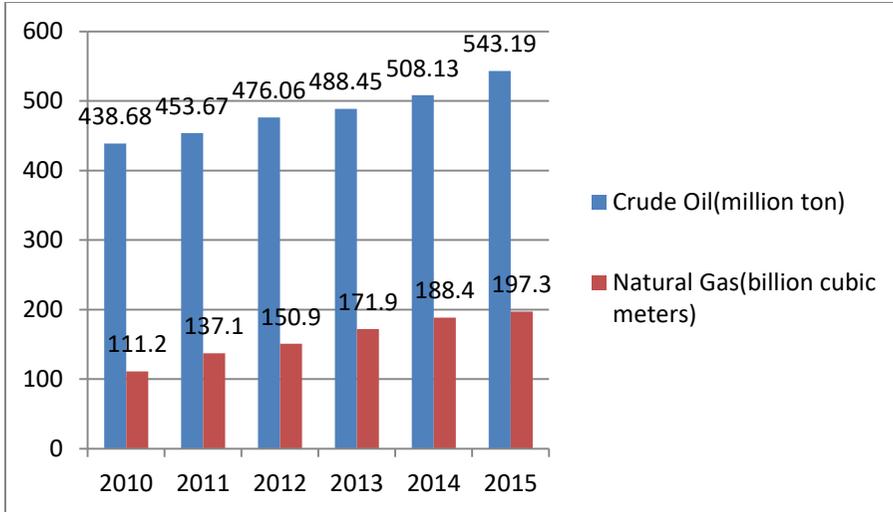


Figure 1. 2010-2015 Consumption of crude oil and natural gas in China Source: BP world energy statistics yearbook 2015

Over past three decades, China's annual growth rate of GDP is about 9.7% which is one of the fastest-growing countries in the world. The rapid development of the national economy has promoted the rapid growth of petroleum demand in China. In 2010, China's crude oil and natural gas consumption were 438.68 million tons and 111.2 billion cubic meters. China's crude oil and natural gas consumption were 543.20 million tons and 197.3 billion cubic meters in 2015 (China National Petroleum Corporation, 2016). Due to the rapid economic development, China's current energy demand is strong. Although China is the world's energy producer, energy production is still difficult to meet the huge energy needs. From 1949 to 1960, China's domestic demand for refined oil and demand for crude oil were all dependent on imports from abroad. In 1961-1979, oil was self-sufficient. During this period, part of the crude oil was also used for export. But in 1993, China became a net importer of oil (Cui, 2010).

As energy-based enterprise, petroleum enterprises play an important role in the national economy that makes great contribution to the development of national and regional economy. China's petroleum enterprises have made great progress over past 60 years. After decades of integration and adjustment, China National Petroleum Corporation (CNPC), Sinopec Group and China National Offshore Oil Corporation (CNOOC) have developed into large integrated energy enterprises and rank in Fortune Global 500. For example, China National Petroleum Corporation ranked third place in the Fortune Global 500 in 2016, revenue for the year is 299,270.6 million dollars and profit is 7,090.6 million dollars. However, there are still some problems in the development of China's petroleum enterprises. With the fluctuation of the international oil price, the situation of world economy became more complex that petroleum enterprises are facing unprecedented challenges. The gap of supply and demand is growing because of energy shortage in China. Research from Chinese academy of sciences reported that supply of crude oil and natural gas resources has been significantly lagging behind the growth of national economy (X. Liu, 2014). From 2010-2015, foreign dependence of China's crude oil and natural gas has been increasing and the dependence of crude oil reached 60.6% by 2015.

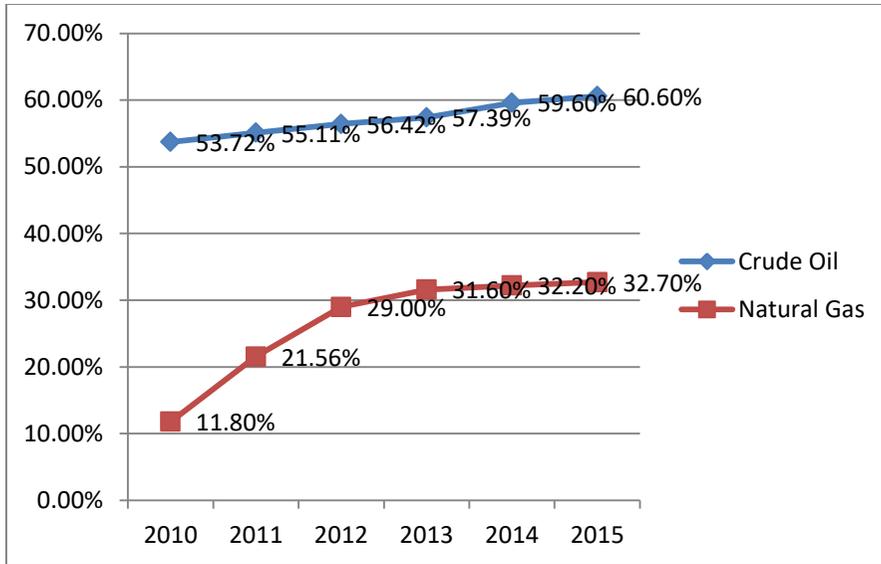


Figure 2. 2010-2015 Foreign dependence of China's crude oil and natural gas
Source: Own creation based on Figure 1. Foreign dependence=Total imports / (domestic production + total imports)*100%

The oil consumption of China is expected to reach 590 million tons by 2020 which lead the supply and demand gap of oil and gas resources will be further expanded. With the high growth of energy consumption, China's oil and gas production is obviously insufficient. Moreover, most of the oil fields have entered the late stage of development, especially the recoverable reserves of high quality has been decreasing. There are still many problems in the process of mining, such as indiscriminate mining and damage to the oil reservoir that resulted in a large number of oil and gas resources cannot be recovered(Z. Zhao, Huo, & Wang, 2011). At the same time, the level of technology in exploration is low that cannot meet the requirement of sustainable development of oil resources. Faced with all these bottleneck problems, petroleum enterprises of China should speed up the reformation and reorganization of their system and implement low-cost strategies of development in order to improve

competitiveness of enterprises in international market. To cope with fierce competition, we should find a suitable way of cost management for China's petroleum enterprises. In this thesis, I will try to learn and absorb the experiences of advanced cost management from western countries so that to contribute to theory of China's strategic cost management. In the meantime to improve the level of cost management of China's petroleum enterprises that to gain competitive advantage in market.

2. Aims of study

The objective of my PhD work has twofold. The first objective is to research the current situation of cost management of petroleum enterprises in China. Investigating what kind of cost management and what kind of tools they applied in cost management of their business that will help researchers who interested in this field to find out the problems existing in petroleum enterprises. Petroleum enterprises have very important position and function in China, if I can find out some problems of enterprises, then we can try to fix the problems. The second objective is based on the first objective to optimize the cost management method and structure of Chinese petroleum enterprises by using strategic cost management that can make contribution to China's economy and make petroleum enterprises have better performance and competitive advantages in markets. I hope after finish the work of my PhD, my research could help Chinese petroleum enterprises to improve their ability of cost management so that to maintain competitive advantage in market.

3. Material and method

The goal of strategic cost management is to provide prompt, reliable and useful information for business decision-making. The basis for obtaining high quality cost information is to find out the cost driver (J. Li, 2009). The cost strategy of enterprise cost strategy not only consider the cost reduction, but also consider the essential factors which restrict the cost of enterprise from the perspective of long-term strategy and competitive advantage. In the premise of certain strategy of enterprise, analyzing the cost driver is the basis of cost reduction and control through the macro level.

The strategic cost management of petroleum enterprises is a systematic process of management. The cost is driven by many cost drivers, which determine the production cost of petroleum enterprises (Deng, 2010). Most of the cost drivers are tangible such as working hours, output, number of workers etc. But part of the cost has been decided before the production such as the scale of enterprises and organizational structure determines the cost of labor force and the size of asset determines the depreciation. Most of these cost drivers are difficult to quantify and not independent of the cost. Cost drivers are interacting with each other that the effect is reflected in the cost. In order to improve the effect of strategic cost management for petroleum enterprises, we need to figure out the relations between these strategic cost drivers and how these strategic cost drivers influence on the cost management of petroleum enterprises.

This chapter will study the strategic cost drivers of petroleum enterprises systematically with Decision Making Trial and Evaluation Laboratory (DEMATEL) in order to find out which cost driver could

influence on the strategic cost management of petroleum enterprises significantly.

3.1 The structure of strategic cost driver of petroleum enterprises

Cost drivers are the structural determinants of the cost of an activity, reflecting any linkages or interrelationships that affect it (Porter, 1985). Traditional cost management usually taking output as the only cost driver. However, research shows that cost driver which are widely accepted in traditional cost management only account for around 15% of the total cost drivers. The other 85% of cost drivers has been influenced on the cost before production activities (Xuemei Yang & Tang, 2003). Such as the size of enterprise, investment, organizational structure, geographical location etc. which defined as the strategic cost drivers. By studying strategic cost drivers, enterprises could find out the cause of the cost and the way of cost reduction.

Strategic cost drivers are basic factors that lead to business costs, and are related to long-term business strategies. According to Michael Porter (Porter, 1988), strategic cost drivers can be identified as economies of scale, learning and spillovers, capacity utilization, linkages among activities, interrelationships among business units, vertical integration, timing of market entry, firm's policy of cost or differentiation, geographic location and institutional factors etc. John Shank and Vijay Govindarajan list cost drivers into two categories which are structural cost drivers and executional cost drivers (Shank & Govindarajan, 1993). Structural cost drivers determine the enterprise's economic structure. The formation of structural cost

drivers usually before production activities such as size of enterprise that requires a long period process of decision-making and is difficult to change after decided. Structural cost drivers not only influence on the cost, but also influence on other cost drivers such as product quality, human resources etc. Executional cost drivers are related to the execution of the business activities. Executional cost drivers generated after the structural cost drivers are decided. Executional cost drivers reflect the enterprise's utilization of resources and the execution effect of the activities, such as capacity utilization.

There are a lot of experts and scholars who did research of strategic cost drivers for enterprises. For petroleum enterprises, most of enterprises reduce cost through the way of improve labor productivity and improve the quality of assets. This paper analyzes the cost management of petroleum enterprises based on the analysis of strategic cost drivers. In the designing framework of strategic cost drivers, this paper takes into account the characteristics of petroleum enterprises such as cleaner production under the classic framework of Porter's.

In this paper, strategic cost drivers of petroleum enterprise are economies of scale, learning ability, vertical integration, geographic location, progress of technology, cleaner production, level of resources, capacity utilization, interrelationship of value chain, total quality management, involvement of employees.

Table 1. Strategic cost drivers of petroleum enterprise

Type of strategic cost drivers	Strategic cost drivers	Number
Structural cost drivers	Economies of scale	D1
	Learning ability	D2
	Vertical integration	D3
	Geographic location	D4
	Progress of technology	D5
	Cleaner production	D6
	Level of resources	D7
Executional cost drivers	Capacity utilization	D8
	Interrelationship of value chain	D9
	Total quality management	D10
	Involvement of employees	D11

Source: Own creation

3.1.1 Structural cost drivers

The economies of scale of petroleum enterprises are different from manufacturing enterprises. Sometimes the scale of investment and production efficiency is not proportional. The cost of production is not lower with the expansion of business scale and the increase of business volume, which cannot reduce the fixed cost of per unit. For

example, Karamay oilfield in Xinjiang province started to exploit in 1955, after over 60 years exploitation, Karamay oilfield is in the late development stage now, the facilities of exploitation is becoming old. With the further development, increased difficulty in exploitation will lead to an increase in investment. Under this circumstance, strategic cost management is becoming more and more important for petroleum enterprises.

The contribution of learning ability to cost mainly comes from two aspects which are internal accumulation and external learning. Internal accumulation is that through practice and learning, employees have full knowledge of new technology and effective method to complete the work. External learning is enterprises try to find out resources that are conducive to improve the value of enterprises in external environment. Such as learning from other enterprises in the same industry, buying or using advanced experience and methods of competitors.

In order to improve the competitive advantage, enterprises may expand the scale of business continuously which to expand the value chain to upstream and downstream enterprises. Vertical integration is the degree to which an enterprise owns upstream and downstream enterprises. Vertical integration of petroleum enterprises can be divided to direction that forward vertical integrate exploration of oil and backward vertical integrate oil refining and oil retailing. Through the integration of upstream and downstream enterprises, petroleum enterprises could optimize the allocation of resources and reduce cost to obtain competitive advantage.

The influence of geographic location on the cost of petroleum enterprises is mainly the difficulty degree of oil and gas exploitation and the cost of crude oil transportation. Located in different oil fields, traffic conditions and economic conditions are not the same. The location of the oil field not only influences on oil and gas exploration but also influence on pipeline transportation, oil refining transportation and retailing. The most significant effect is to increase the cost of each node in the value chain of the petroleum enterprise.

Due to the decline of oil and gas resources, exploitation became more and more difficult in recent years for petroleum enterprises. Petroleum enterprises can no longer only rely on current technology of exploitation. In order to compete with big petroleum enterprises they must develop new technology. For example, the application of three-dimensional seismic technology improved the observation accuracy of geological structure which increased the success rate of exploration, reduce the cost of exploration.

Environmental issues have become the focus of the whole world. Most countries take the ecological security as a major strategy for economic development. As a developing country, China has the problem of energy shortage, low resources for per capital and serious environmental pollution. To develop cleaner production is conducive to improve energy efficiency and the energy structure (Xiaolong Yang, 2013). The proportion of environmental cost is increasing in the production cost of petroleum enterprises. Because the current methods of pollution control are not effective, to establish cost management on the basis of cleaner production is conducive to control the environmental cost and improve the competitiveness of

enterprises. But in the process of improving the environment or avoiding pollution, petroleum enterprises could increase cost because of equipment of cleaner production and acquisition of cleaner production technology, which is an important structural cost driver influence on the cost of petroleum enterprises.

The level of oil resources mainly refers to the potentiality of oil and gas and geographical features of the area, which reflects the probability of oil and gas exploration and the difficulty degree of exploration and development. The characteristics of oil resources determine the development mode and production cost of petroleum enterprises. Different stage of oilfield has different level of resources, which makes the cost of production increase year by year. At the same time, the economic benefits are decreasing year by year. In the early stages of development, due to high strata pressure single well production increasing lead to total production increasing. After the peak period, strata pressure becomes lower and lower will lead to decreased capacity of production. Petroleum enterprises need to invest more money to fix this. Therefore, in the process of exploration, the level of resources has a very important impact on the cost of petroleum enterprises.

3.1.2 Executional cost drivers

Capacity utilization is in the premise of certain scale of investment to improve the efficiency of the use of assets, such as through the reformation of the production process or technical improvements to improve production efficiency. Usually, the higher the utilization of production capacity, the lower fixed cost of unit product that means high capacity utilization will help enterprise to reduce the cost per

unit of product. The type of petroleum enterprises is capital intensive enterprise. Petroleum enterprises require a lot of investment and most of assets are fixed assets that lead to huge fixed cost in the production process such as depreciation and cost of labor force. Therefore, capacity utilization is a very important executional cost driver for petroleum enterprises.

The value chain of petroleum enterprises can be divided into internal value chain and external value chain. The interrelationship of internal value chain mainly related to every production activities of petroleum enterprises. The interrelationship of external value chain involves the value chain of whole oil industry, including exploration, exploitation, oil refining and sales etc. Internal value chain can be improved by modifying the relationships among every department in the enterprise or by reorganizing the organizational structure to coordinate the activities which could improve the activity efficiency. External value chain reflects the dependency of petroleum enterprises with upstream and downstream enterprises. External value chain can affect the cost structure of petroleum enterprises such as cost of transportation and cost of assets.

Total quality management (TQM) consists of organization-wide efforts to install and make permanent a climate in which an organization continuously improves its ability to deliver high-quality products and services to customers (Lorente, Dewhurst, & Dale, 1998). For petroleum enterprises, total quality management means that controlling the defect in the production process. The purpose of total quality management is to reduce unnecessary loss and cost to improve the competitiveness of petroleum enterprises. The

production of petroleum enterprises is different from manufacturing industry (H. Zhao, 2014). Usually a petroleum enterprise has many production areas and the location is far away from cities lead to complex working conditions. Because of these factors, total quality management is one of the effective ways to reduce cost.

People are the most important resources in enterprise. Every employee's behavior is related to the implementation of enterprise strategy and enterprise cost. The participation and responsibility of employees directly affect the total cost of enterprise. As large state-owned enterprises in China, the central planning economy has a deep impact on petroleum enterprises. Many ordinary employees in petroleum enterprises generally believe that the implementation of the strategy is the task of management department, the cost reduction is the responsibility of the financial department and ordinary employees have nothing to do with this. However, the production of petroleum enterprises is complex and the management is much more difficult than other type of enterprises. Only depend on managers or financial department cannot achieve the goal of cost control. Therefore, petroleum enterprises should encourage all employees to participate in strategic cost management of enterprises through incentive system, so that to reduce cost and improve the competitive advantage.

3.2 Model

There are two categories to classify the strategic cost drivers. One is divided into structural cost driver and executional cost driver. The other one is divided strategic cost drivers into three levels which strategic, tactical and operational cost drivers. The regardless of

which category, most of the researches are qualitative analysis. There are a few researches of quantitative analysis based on cost drivers selection or combination. Such as Schniederjans and Garvin used analytic hierarchy process to select cost driver which made contribution to quantization of strategic cost driver (Schniederjans & Garvin, 1997). According to the problem of lack quantitative analysis, this thesis will combine qualitative with quantitative analysis of strategic cost drivers of petroleum enterprises by using Decision Making Trial and Evaluation Laboratory (DEMATEL). Hoping the result of DEMATEL could be the guidance of cost management of petroleum enterprises with good effect. There are a lot of strategic cost drivers of petroleum enterprises. Enterprises cannot take care of all cost drivers in the same time. Therefore, enterprises need to find out and control the key cost drivers which have the greatest impact on cost. If enterprises could control key cost drivers means they controlled most part of cost of enterprises.

Decision Making Trial and Evaluation Laboratory methodology is proposed to for researching and solving complex and intertwined problem groups because of its capability in verifying interdependence between variables and try to improve them by offering a specific chart to reflect interrelationships between variables (Falatoonitoosi, Leman, Sorooshian, & Salimi, 2013). The Decision Making Trial and Evaluation Laboratory method developed by the Geneva Research Centre of the Battelle Memorial Institute, which was developed to study the structural relationships in a complicated cluster of problems (Lu, Rau, Liou, & Yang, 2014). Because DEMATEL can develop the structural relationships in a complicated cluster of problems and describe the interrelationships among the factors to reveal key factors,

the method is widely used in various fields. Such as analyzing green supply chain (Zhigang Wang, Mathiyazhagan, Xu, & Diabat, 2016), DEMATEL method used in the multi-criteria decision making (C.-W. Li & Tzeng, 2009), analyzing key factor of hospital service (Shieh, Wu, & Huang, 2010), personnel estimation (Roy & Misra, 2012), modelling for causal interrelationships (Siti Aissah Mad Ali & Sorooshian, 2016), for medical tourism development (C.-A. Chen, 2012) etc. DEMATEL method is to use the degree of mutual influence between the factors to calculate the degree of center and the degree of cause, so as to determine the importance and value of each factor. The method combines qualitative with quantitative methods to research on complex system problems.

The DEMATEL method is described as the following,

Step 1, identify the factors that influence the problem, set the number of factor as $D_1, D_2 \dots D_n$.

Step 2, find out the direct-relation matrix. The matrix determine by relationship between factors according to a number of experts' opinion. The influence scale set 0 as no influence, 1 as low influence, 2 as medium influence, 3 as high influence and 4 as very high influence (0= no influence, 1= low influence, 2= medium influence, 3= high influence, 4=very high influence) for comparison of factor influence. If there are Z experts compare n factors, the result of each expert can be described as direct relation matrix of $n \times n$, which includes factor D_{ij}^k illustrate that influence between factor D_i and D_j given by k^{th} expert, ij means factor D_i has influence on factor D_j . The

diagonal of the matrix is zero because factor has no influence on itself in DEMATEL.

$$D = \begin{bmatrix} 0 & D_{12} & \cdots & D_{1n} \\ D_{21} & 0 & \cdots & D_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ D_{n1} & D_{n2} & \cdots & 0 \end{bmatrix}$$

To collect all experts' opinion to calculate the average direct relation matrix of $X = [A_{ij}]$, which can be calculated by using equation as the following,

$$A_{ij} = \frac{1}{Z} \sum_{k=1}^Z D_{ij}^k \quad (1)$$

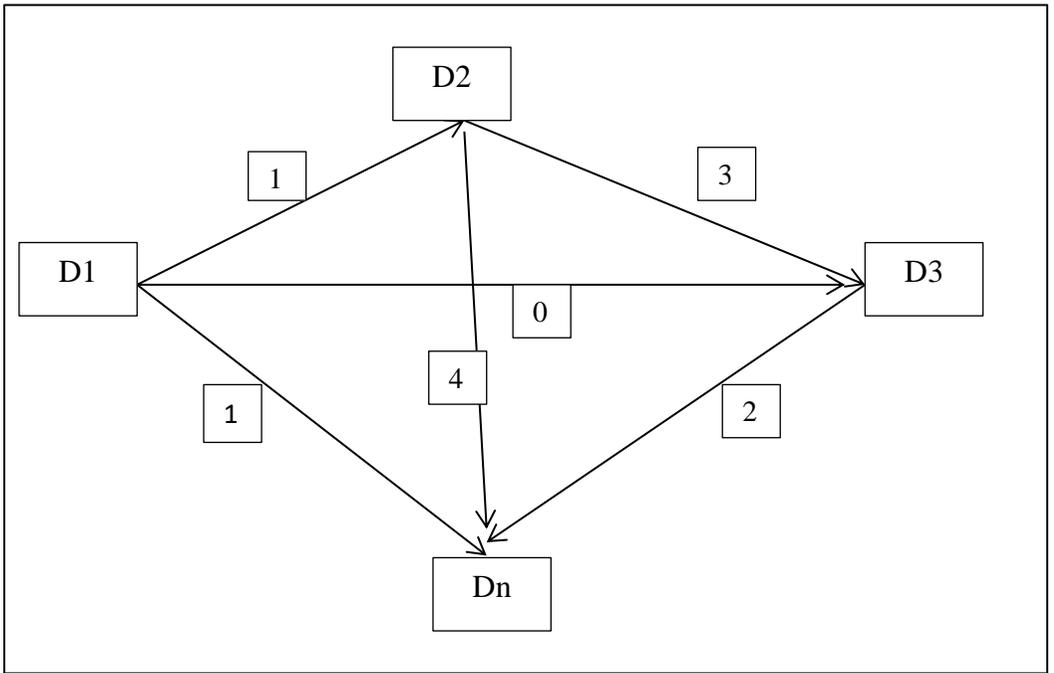


Figure 3. Example map of influence network Source: Own creation

Step 3, to normalize the direct relation matrix X to the matrix Y . Matrix Y presents the relative intensities of the direct relations.

$$S = \max\{\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}, \max_{1 \leq j \leq n} \sum_{i=1}^n a_{ij}\} \quad (2)$$

$$Y = \frac{X}{S} \quad (3)$$

According to equation 2 and equation 3 we can calculate the normalizing matrix. S means sum each row and each column to find out the max number, this number is S.

Step 4, to calculate total relation matrix T.

$$T = Y^1 + Y^2 + \dots + Y^n = Y(I - Y)^{-1} \quad (4)$$

Total relation matrix is sum of normalizing matrix, when n is large enough the equation can be described as equation 4. I represent identity matrix in equation 4. T_{ij} indicate that the relationship between D_i and D_j including direct and indirect influence. Through analysis of T_{ij} , we can find out the result of each factor $D_1, D_2 \dots D_n$'s influence degree, affected degree, center degree and cause degree.

Step 5, influence degree can be calculated as sum of T_{ij} in each row, we set it as e_i , e_i is the influence degree of D_i in the row to other factors in the row, the equation as following,

$$e_i = \sum_{j=1}^n T_{ij} \quad (5)$$

Affected degree can be calculated as sum of T_{ij} in each column, we set it as a_j , a_j is the affected degree of D_j in the column to other factors in the column, the equation as following,

$$a_j = \sum_{i=1}^n T_{ij} \quad (6)$$

The sum of influence degree and affected degree call center degree of factors. This index represents factor's position and importance in the

system, the bigger number of center degree, the more important in the system. Center degree of D_i can be calculated as following,

$$c_i = e_i + a_j \quad (7)$$

Because e_i and a_j corresponding the same factor, so $i=j$.

The cause degree can be calculate as subtraction of influence degree and affected degree, which influence degree minus affected degree. The equation of cause degree as the following,

$$u_i = e_i - a_j \quad (8)$$

It is same as equation 7 that $i=j$. If cause degree $u_i > 0$ that means influence degree is bigger than affected degree, the factor influences other factors. If $u_i < 0$ that means influence degree is smaller than affected degree the factor affected by other factors.

Step 6, creating visual diagram and reorder factors according to the calculated degree to find out key factors.

3.3 Analyzing strategic cost drivers by using DEMATEL model

In this thesis, I will use DEMATEL model to analyze strategic cost drivers of petroleum enterprises. First, creating direct relation matrix based on experts' opinion. Second, creating total relation matrix after created direct relation matrix. Third, to calculate the influence degree, the affected degree, the center degree and the cause degree among each cost driver. Last, according to the result to determine the key strategic cost drivers.

4. Result and discussion

4.1 Result

4.1.1 Creating direct relation matrix

I used the method of combining interview and scoring sheet to determine the influence relationship among each cost driver in the thesis. First of all, I interviewed relevant experts and scholars from Karamay Oilfield, Tarim Oilfield, China University of Petroleum, Xinjiang College of Petroleum and China National Petroleum Corporation.

I determined the strategic cost drivers of petroleum enterprises in China on the basis of experts' opinion. Then, designed scoring sheet of strategic cost drivers and invited ten experts to give the mark to the influence among strategic cost drivers. After experts' scored, I collected all data and analyzed the data, then decided to use mode of this data set as the basis to construct the direct relation matrix M of strategic cost drivers of petroleum enterprises.

Table 1. List of experts for interview

Name	Position	Institution
Zhenquan Wang	Professor	China University of Petroleum(Karamay branch)
Hongkui Ge	Professor	China University of Petroleum(Karamay branch)
Zongjie Mu	Senior engineer	China University of Petroleum(Karamay branch)
Luguang Li	General manager	Tarim Oilfield of China National Petroleum Corporation
Jiangchuan He	Deputy general manager	Tarim Oilfield of China National Petroleum Corporation
Zhaoji Liang	Professor	Xinjiang College of

		Petroleum
Pingzheng Cui	Professor	Xinjiang College of Petroleum
Ganying Zhang	Professor	Xinjiang College of Petroleum
Yufen Cai	Professor	Xinjiang College of Petroleum
Youlin Zhang	General manager	Sinopec (Karamay branch)

Source: Own creation

Table 2. Direct relation matrix M

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
D1	0	0	0	3	3	4	0	3	2	2	2
D2	1	0	0	0	4	0	0	3	0	4	3
D3	4	1	0	4	1	0	0	0	4	0	0
D4	2	1	4	0	1	0	1	0	3	0	0
D5	3	3	2	1	0	4	3	4	2	0	2
D6	4	1	2	1	4	0	1	2	2	4	3
D7	4	2	2	2	3	3	0	2	4	3	0
D8	2	2	0	0	2	1	0	0	0	3	2
D9	0	1	4	2	0	0	0	0	0	1	0
D10	1	3	0	0	1	2	0	2	1	0	4
D11	0	3	0	0	0	3	0	1	0	3	0

D1, D2 ... D11 represent strategic cost drivers of petroleum enterprise. The name of factors see from table 10. Source: Own creation

4.1.2 Normalizing the direct relation matrix

Normalizing the direct relation matrix M according to equation (2) and (3) by using MATLAB software, the normalizing direct relation matrix N as the following,

Table 3. Normalizing direct relation matrix N

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
D1	0	0	0	0.12	0.12	0.16	0	0.12	0.08	0.08	0.08
D2	0.04	0	0	0	0.16	0	0	0.12	0	0.16	0.12
D3	0.16	0.04	0	0.16	0.04	0	0	0	0.16	0	0
D4	0.08	0.04	0.16	0	0.04	0	0.04	0	0.12	0	0
D5	0.12	0.12	0.08	0.04	0	0.16	0.12	0.16	0.08	0	0.08
D6	0.16	0.04	0.08	0.04	0.16	0	0.04	0.08	0.08	0.16	0.12
D7	0.16	0.08	0.08	0.08	0.12	0.12	0	0.08	0.16	0.12	0
D8	0.08	0.08	0	0	0.08	0.04	0	0	0	0.12	0.08
D9	0	0.04	0.16	0.08	0	0	0	0	0	0.04	0
D10	0.04	0.12	0	0	0.04	0.08	0	0.08	0.04	0	0.16
D11	0	0.12	0	0	0	0.12	0	0.04	0	0.12	0

The number is accurate to two decimal places Source: Own calculation

4.1.3 Creating total relation matrix

After normalized the direct relation matrix, we can create total relation matrix T based on Table 12 and equation (4) by using MATLAB.

Table 4. Total relation matrix T

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
D1	0.15	0.14	0.11	0.20	0.25	0.29	0.05	0.25	0.20	0.23	0.22
D2	0.15	0.13	0.05	0.05	0.26	0.13	0.04	0.24	0.08	0.28	0.25

D3	0.24	0.11	0.10	0.23	0.13	0.08	0.03	0.08	0.25	0.08	0.07
D4	0.17	0.10	0.23	0.09	0.12	0.07	0.06	0.07	0.21	0.07	0.06
D5	0.31	0.28	0.20	0.16	0.20	0.32	0.16	0.33	0.23	0.22	0.26
D6	0.33	0.21	0.19	0.16	0.32	0.19	0.09	0.26	0.22	0.34	0.29
D7	0.34	0.24	0.22	0.21	0.30	0.29	0.06	0.26	0.32	0.30	0.18
D8	0.16	0.17	0.05	0.05	0.18	0.14	0.03	0.11	0.07	0.23	0.19
D9	0.06	0.08	0.20	0.13	0.05	0.03	0.01	0.04	0.06	0.08	0.04
D10	0.13	0.22	0.05	0.05	0.15	0.18	0.03	0.18	0.10	0.13	0.27
D11	0.08	0.19	0.04	0.03	0.09	0.19	0.02	0.13	0.05	0.22	0.10

The number is accurate to two decimal places Source: Own calculation

4.1.4 Calculating the influence degree, the affected degree, the center degree and the cause degree

After created total relation matrix T, we can calculate the influence degree, the affected degree, the center degree and the cause degree of strategic cost drivers based on equation (5), (6), (7), (8).

Table 5. Influence degree, affected degree, center degree and cause degree of strategic cost drivers

	e_i	a_j	c_i	u_i
D1	2.0825	2.1338	4.2163	-0.0513
D2	1.6505	1.8772	3.5277	-0.2267
D3	1.3880	1.4212	2.8092	-0.0332
D4	1.2427	1.3492	2.5919	-0.1065

D5	2.6827	2.0426	4.7253	0.6401
D6	2.6025	1.9008	4.5033	0.7017
D7	2.7195	0.5751	3.2946	2.1444
D8	1.3663	1.9380	3.3043	-0.5717
D9	0.7666	1.7747	2.5413	-1.0081
D10	1.2404	2.1794	3.4198	-0.9390
D11	1.1424	1.6921	2.8345	-0.5497

e_i is the influence degree of each strategic cost driver, a_j is the affected degree of each strategic cost driver, c_i is the center degree of each strategic cost driver and u_i is the cause degree of each strategic cost driver. Source: Own calculation

4.1.5 Creating visual diagram

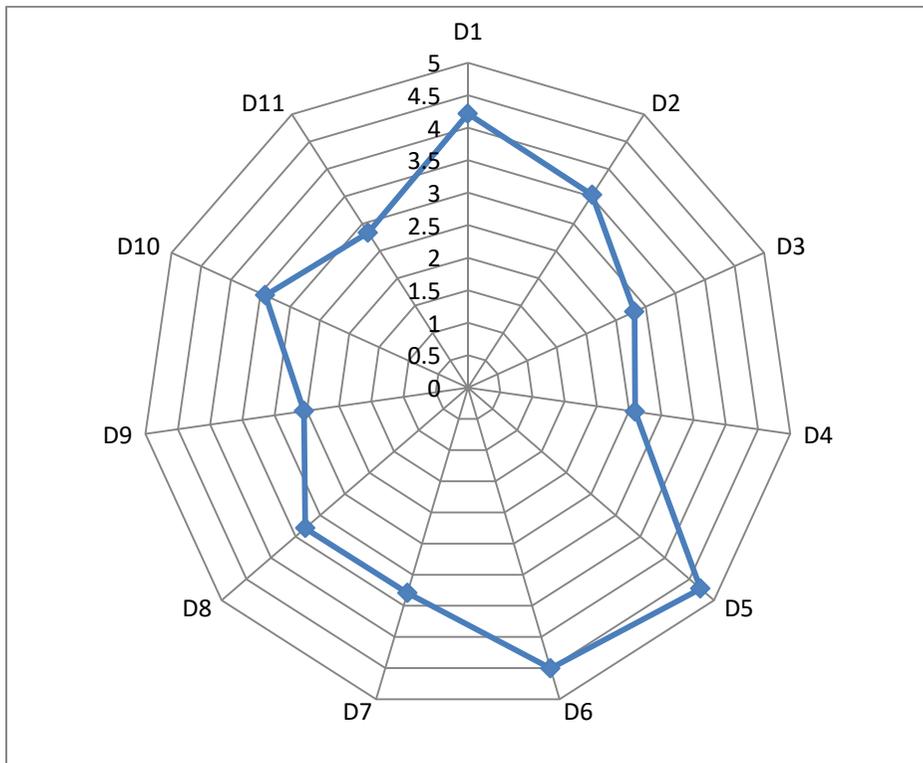


Figure 4. Center degree of strategic cost drivers

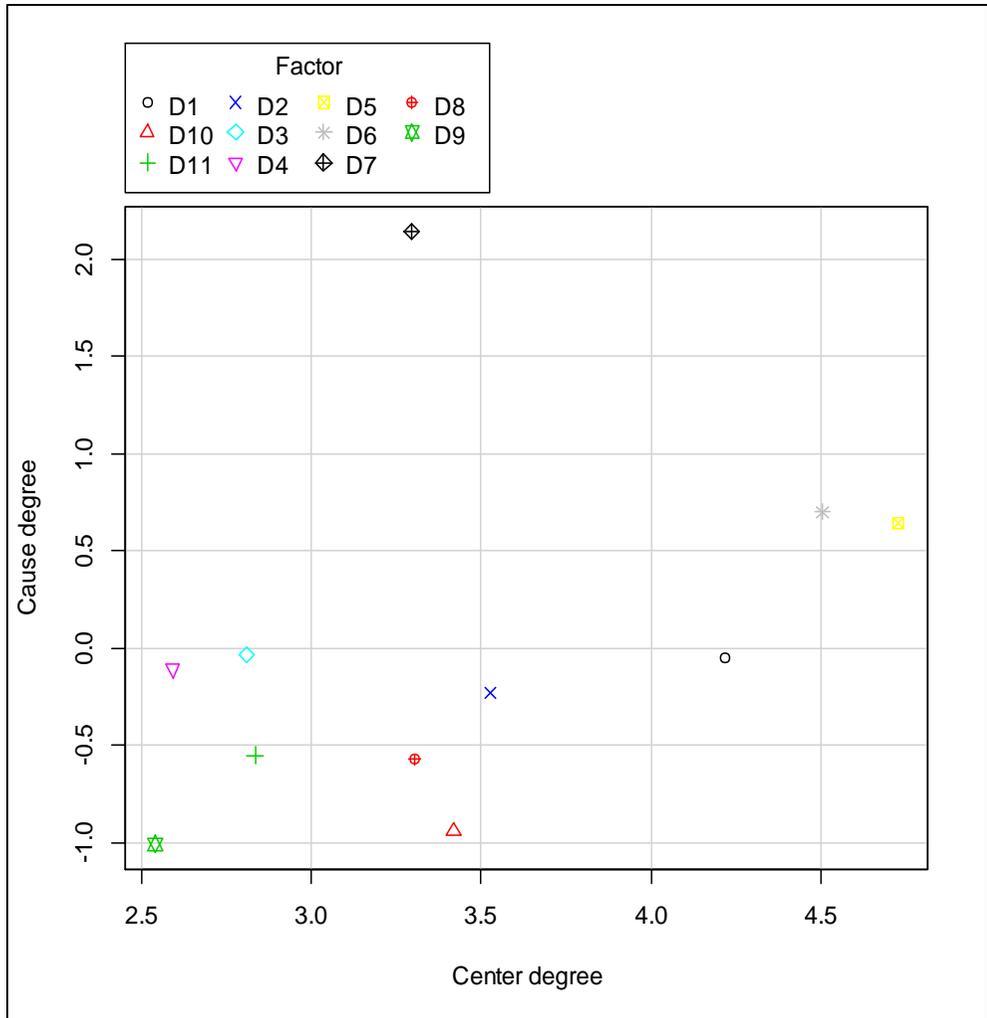


Figure 5. Scatter plot of center degree and cause degree

After created visual diagram, we can see that order of center degree follow the order as D5, D6, D1, D2, D10, D8, D7, D11, D3, D4, D9. The center degree indicates that the importance of cost drivers in the cost driver system. Therefore, based on the result, progress of technology, cleaner production, economies of scale, learning ability and total quality management have bigger center degree that means petroleum enterprises in China should pay more attention to these cost drives in process of strategic cost management. From figure 17

we can see that D5, D6, D7 are bigger than zero, and D1, D2, D3, D4, D8, D9, D10, D11 are smaller than zero. As mentioned before, when cause degree bigger than zero, the factor influence other factors thus D5, D6, D7 which progress of technology, cleaner production, level of resources are the factors influence on other factors.

After analyzed strategic cost drivers of petroleum enterprises in China by using DEMATEL model, we can find out key cost drivers of the eleven strategic cost drivers. Center degree of progress of technology, cleaner production, economies of scale bigger than 4; center degree of learning ability, total quality management, capacity utilization, and level of resources bigger than 3, which also have important position in the system of strategic cost management. Thus, the result of analysis of strategic cost drivers shows that progress of technology, cleaner production, economies of scale are key cost drivers for petroleum enterprises in China. Although, the center degree of level of resources is not high enough, but the cause degree of the level of resources is very high that means level of resources has very big impact on other cost drivers.

Although result shows that progress of technology, cleaner production, economies of scale are key cost drivers, it does not mean that other cost drivers are not important. Involvement of employees, vertical integration, geographic location and interrelationship of value chain are also main cost drivers in the strategic cost management system. The reason of the result is because since the 1990s, a large number of cost management theories and research methods were introduced into China which applied for petroleum enterprises. After several years, the development of petroleum enterprises is getting

better and they have relative mature management system. Cost drivers like involvement of employees, vertical integration and geographic location will not have a big change and challenge for petroleum enterprises in short term. Therefore, they are main cost drivers but not the key cost drivers.

Another reason is people started to concern about the ecological environment and social problems in recent years. The Chinese government also focused on the environmental issues that restricted the carbon emissions of petroleum enterprises through legislation of laws and regulations to push petroleum enterprises to improve their cleaner production and corporate social responsibility. Due to the particularity of production, which have negative influence on ecological environment, in order to implement cleaner production to reduce carbon emissions, petroleum enterprises continuous to increase the investment in equipment of cleaner production and advanced technology. Therefore, cost drivers like cleaner production, progress of technology will be the key cost drivers for the cost of petroleum enterprises in next few years.

4.2 Optimizing key cost drivers

4.2.1 Progress of technology

In recent years, China's petroleum enterprises continue to increase the investment in scientific and technological innovation. In exploration process, three-dimensional seismic exploration, remote sensing technology and computer data and image processing technology were applied for petroleum enterprises as well as advanced deep water exploration technology accelerated the exploration of oil and gas.

These technologies improved the production efficiency and increased oil and gas reserves of petroleum enterprises (Xiao, 2013).

China has a very high percentage of low permeability reservoirs, ultra-low permeability reservoirs and heavy oil of oil resources. According to the characteristic, petroleum enterprises should improve the technology of forecasting the distribution of remaining oil and gas resources, heavy oil steaming, solvent extraction, in-situ combustion and other advanced technology such as technology of low-cost for low permeability reservoirs. The difficulty of innovation is lack of talent. If petroleum enterprises want to obtain more advanced technology for the development, they need to improve the cooperation with scientific research institutions and first-class universities. Petroleum enterprises cooperate with scientific research institutions and first-class universities is conducive to mutual knowledge acquisition and promote the development of technological innovation to reduce innovation cost and shorten the innovation cycle, which improve the performance of technological innovation while reduce the total cost of petroleum enterprises. Petroleum enterprises also need to set up appropriate strategies to improve the level of technological innovation. The strategy will push the enterprise to obtain more advanced technology, the more advanced technology petroleum enterprises owned, the more profit they will earn.

4.2.2 Cleaner production

Oil and gas resources are an important part of the ecological environment, petroleum enterprises need to consider the sustainability while they exploit the resources. Therefore, it is necessary to establish a system to evaluate the bearing capacity of

ecological environment where the oil and gas resources located. Then, petroleum enterprises need to prevent and reduce the geological disasters in the process of exploitation and exploit the resources in a scientific way. It is estimated that the cost of traditional mode of production and the damage to the environment is much higher than the cost of using cleaner production (Hong, 2016). Therefore, implementation of cleaner production is necessary for petroleum enterprises.

Strategic cost management under the condition of cleaner production should focus on efficiency, which to produce more products or provide more services with the most economical way. On the one hand, assuming that output is invariant, calculating the cost of total life-cycle environmental costs of cleaner production technology, combined with the accounting cost of the cleaner production technology to make the cost as low as possible; on the other hand, comparing the total benefits of all cleaner production technologies, including economic benefits, social benefits and environmental benefits, then choose the most efficient cleaner production technology. Petroleum enterprises can design the cost management system from the perspective of cleaner production, which is a breakthrough in traditional cost management.

4.2.3 Economies of scale

The main purpose of the expansion of the scale of investment in oil production is to stabilize production. If petroleum enterprises want to reduce cost of production in essence, they need to continuous increase investment in exploration and optimizing the structure of assets. At the same time, they need to find high-quality reserves to

increase the level of oil and gas resources they owned. If they have high-quality reserves that can reduce oil and gas costs from the source.

For example, China National Petroleum Corporation implemented multi-layer fracturing, horizontal well drilling and deep well drilling in key exploration areas such as low permeability, carbonate rock and volcanic rock in 2015. Those actions obtained an important strategic discovery in main exploration area, which improved the level of oil and gas resources CNPC owned. Through a series of exploration, CNPC found a large number of oil and gas resources.

Table 6. Oil and gas reserves and exploration workload of CNPC

	2014	2015	2016
Newly discovered petroleum reserves (million ton)	689.80	728.17	649.29
Newly discovered natural gas reserves (billion square meter)	484.0	570.2	541.9
2D seismic (kilometer)	19170	15909	24885
3D seismic (square kilometer)	11739	9095	8764
Exploratory well (unit)	1584	1588	1656
Preliminary prospecting well (unit)	910	924	865
Test well (unit)	674	664	791

Source: http://www.cnpc.com.cn/cnpc/ktysc/ktysc_index.shtml

Through increasing investment in exploration to obtain more high-quality resources, petroleum enterprises could reduce the follow-up cost of development and production.

5. Conclusions

5.1 Conclusions

Based on the previous analysis the following conclusions can be drawn.

There are some problems of cost management in China's petroleum enterprises. Cost management of petroleum enterprises become more and more difficult with the lack of resources, increasing difficulties in exploration that lead to cost of oil and gas continue to rise etc. in China. Although China's petroleum enterprises have taken a variety of cost management tools and methods such as target costing and budget management, there are still many problems existed. Therefore, petroleum enterprises should implement strategic cost management and innovate the cost management method, expand the scope of cost management to reduce cost that to obtain competitive advantage.

This research analyzed strategic cost drivers by using Decision Making Trial and Evaluation Laboratory (DEMATEL) in order to find out which cost driver could influence on the cost management of petroleum enterprises in China.

There are eleven strategic cost drivers of petroleum enterprises in China based on the experts' opinion that including economies of scale, learning ability, vertical integration, geographic location, progress of technology, cleaner production, level of resources,

capacity utilization, interrelationship of value chain, total quality management, involvement of employees

Among the eleven strategic cost drivers, three strategic cost drivers are selected to be key cost drivers which are progress of technology, cleaner production and economies of scale by using DEMATEL model.

Although other eight strategic cost drivers are not key strategic cost drivers, cost drivers of learning ability, vertical integration, geographic location, level of resources, capacity utilization, interrelationship of value chain, total quality management, involvement of employees are also very important strategic cost driver in the cost management system of petroleum enterprises in China.

After calculated all these cost drivers, we can clearly know the importance of strategic cost driver to cost management system. We can optimize key strategic cost drivers to help petroleum enterprises reduce cost and obtain competitive advantage, in the meantime also pay attention to other strategic cost drivers.

Through strategic cost driver analysis, enterprises could know exactly which cost driver is important and modify the cost management methods based on the analysis.

5.2 Limitations

In this dissertation, only the petroleum enterprises from Xinjiang province were selected for field research. However, because the production of petroleum enterprises is affected by various factors such as the condition of crude oil, geological conditions and social

environment that lead to the difference of cost of oil and gas production. To some extent, it affects the general applicability of the research.

The occurrence of cost is the common result of many cost drivers, and different cost driver has different contribution to the total cost. Therefore, it is necessary to establish a quantitative model to analyze the relationship between cost drivers and cost to determine the relative importance of each cost driver and provide strategic information for the implementation of strategic cost management. However, because most of the strategic cost drivers are difficult to quantify accurately that make it difficult to establish an accurate model to describe these complex relationships. This is also a question that needs further research in this dissertation.

6. New scientific result

1. Identification of cost management problems of Chinese petroleum enterprises (integration of internal and external environment is not enough; there is no systematic cost management; the budget management does not cover all costs) and the main causes of problems (the lack of strategic thinking, cost management methods and techniques are obsolete, the scope of cost management is narrow)
2. Introduced the Decision Making Trial and the Evaluation Laboratory (DEMATEL) model to quantify the strategic cost drivers.
3. Identification of eleven strategic cost drivers which have influence on cost management of petroleum enterprises. Find out three key cost drivers by using DEMATEL model. The three key

cost drivers are the progress of technology, cleaner production and economies of scale.

4. Although the center degree of level of resources is not higher than three key cost drivers, the cause degree of level of resources is very high in this case that means level of resources has big impact on other cost drivers.

7. Publications in the field of the dissertation

CAI XIANGYU, DING JIE. (2017): Research on the problems and countermeasures of enterprise cost management [企业成本管理存在的问题及对策研究]. *Logistics Engineering and Management*, 39(10): 124-125.

CAI XIANGYU, DING JIE, CSONKA ARNOLD. (2017): Research on cost management of small and medium-sized enterprises in China-case study of Xinjiang province. *Technology and Economic Guide*, 26(3): 152-153.

CAI XIANGYU. (2018): Analysis of Strategic Cost Drivers of Chinese Petroleum Enterprises by Using DEMATEL. *Regional and Business Studies*. (In Press)