2011

AN EMPIRICAL ANALYSIS OF AUTOMOTIVE MANUFACTURERS SUPPLY CHAIN PERFORMANCE IN CHINA

Wan Ling

PHD

AN EMPIRICAL ANALYSIS OF AUTOMOTIVE MANUFACTURERS SUPPLY CHAIN PERFORMANCE IN CHINA

Ling, Wan

Award date:
2011

Awarding institution:
University of Plymouth

AN EMPIRICAL ANALYSIS OF AUTOMOTIVE MANUFACTURERS SUPPLY CHAIN PERFORMANCE IN CHINA

by

Ling wan

A thesis submitted to the University of Plymouth
in partial fulfillment for the degree of

DOCTOR OF PHILOSOPHY

International Shipping and Logistics Group
Plymouth Business School

2010

AN EMPIRICAL ANALYSIS OF AUTOMOTIVE MANUFACTURERS SUPPLY CHAIN PERFORMANCE IN CHINA

by

Ling wan

A thesis submitted to the University of Plymouth
in partial fulfillment for the degree of

DOCTOR OF PHILOSOPHY

International Shipping and Logistics Group
Plymouth Business School

2010

Copyright statement

Signature of Student

AN EMPIRICAL ANALYSIS OF AUTOMOTIVE MANUFACTURERS SUPPLY CHAIN PERFORMANCE IN CHINA

by

Ling wan

A thesis submitted to the University of Plymouth
in partial fulfillment for the degree of

DOCTOR OF PHILOSOPHY

International Shipping and Logistics Group
Plymouth Business School

2010

Abstract **Ling Wan**

Chinese automotive supply chain management has gained considerable attention from academic and practical research. There is ample work on supply chain management, however research on supply chain performance measurement and improvement is rare. The research develops a framework for the evaluation of automotive supply chain performance in China. In addition, the research presents indications from a study of Chinese automotive companies with regards to their evaluation and attempts to propose some alternatives for future improvement.

Objectives

The objectives of the thesis are:

1) Investigating and analyzing the current state of supply chain management practices in the Chinese automotive industry.
2) Identifying potential drawbacks of Chinese automotive manufacturers supply chain operations and trying to provide optimal solutions for the weakness.
3) Attempting to develop a balanced and comprehensive measurement framework to evaluate supply chain operations for the automotive industry.

Design/methodology/approach

Analytic Hierarchy Process (AHP) methodology divides the research into two parts: performance evaluation and continuous improvements. The first phase aims at evaluation of the supply chain performance of Chinese automotive manufacturers. The second phase aims to find improvement alternatives from the practice based on the first phase. Both qualitative and quantitative methods have been taken into consideration. The data collection procedure was carried out in three stages: pre-survey, getting the measurement scale and collecting metrics data. Primary data were collected through semi-structured interviews, archival documentation and an exploratory survey.

Research limitations/Suggestion

Empirical research showed these limitations: Firstly, a limited sample number of Chinese automotive manufacturers were involved and the distribution of automotive companies' survey may be different from that in large scale investigation. Secondly, the importance of performance measures are derived from the survey, and the empirical investigation may have different results because of participants' managerial concerns, thus the possibility of respondent bias cannot be ruled out. Even the research has limitations, however the research based on deeply investigation and give practical suggestions. Compared to previous research, this research is more comprehensive and reliable, and suggestions are more applicable. Further research is necessary to focus on the performance of supply chain integration and address participants' relationship, such as suppliers, retailers and customers.

List of contents

Contents

List of Tables

List of Figures

Acknowledgements

There are many people I would like to thanks, including my family, my supervisor and the people who participant in the research. Without their valuable help, this research would not have been feasible.

Firstly, I should express my appreciation and gratitude to my family. They have had spent long period time on taking care of me when I was facing a lot of emotional and psychological stresses during the research. Without them, this thesis could not have been produced.

Secondly, I would like express my sincerest gratitude and appreciation to my supervisor, Professor Michael Roe, for his continue encourage when I was in a critical illness and offer invaluable suggestions to support my research. My gratefulness also goes to Dr Irma Pasukeviciute, acting as my second superviseors, Dr Tengfei Wang, Dr Dongping song, for their helpful criticism and useful comments.

Thirdly, I also express my thankfulness to all pre-survey and interview's participants for their precious time and kind support. During the interviews, they were very friendly and patient to answer all my questions and share their experiences and insight regarding automotive companies and its supply chain system. Mr. Mingzhi Li and Mr. Lijun Hou need to special mentioned for their unselfishly help and support on the research data collection.

Lastly, I wish to extend the expression of my appreciation and gratitude to many participants including automotive staffs who I have asked data for the research. Some customers I have done questionnaires with and some colleagues who give me valuable information on AHP method.

AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

Word count of main body of thesis: 66, 548

Signed ....Wan..........

Date ....2010. Sep. 25....

Chapter 1 Introduction

In this section, the thesis first presents a brief review of the research from three ways: in the first part, the thesis introduces the research background and lists reasons for selection of the automotive industry. Then the thesis presents the objectives of the research. In this section, the thesis also demonstrates the research main contents and main issues which arose during practical investigation. Lastly, a brief summary of each chapter is fully presented, and a structure of the thesis also is attached.

1.1 Research overview

Since China implemented an opening-up policy in 1979, following 30 years of reforms, its economy has developed at an unprecedented rate, and that momentum has been held steady into the 21st century. The modernization of China's economy provided significant opportunities for both multinational automotive companies doing business in China and domestic Chinese automotive companies (Wang and Yu 2006). The result is that the Chinese automotive industry has grown dramatically. The impact of the Chinese automotive industry on the global vehicle industry is also becoming enormous, both as a vehicle market and as a vehicle exporter to other markets. However, at the same time, there are growing concerns over the sustainability of the development of the Chinese automotive industry, such as high manufacturing cost, low operational efficiency and lack of standardization for supply chain management, which bring additional problems (Wang and Yu 2006; Fu and Zhang 2008).

In the past years, many researchers have researched the Chinese automotive industry in terms of automotive technology, market strategy and financial analysis. However much less research can be found on automotive supply chain management. Also researchers are more specific on the theory of supply chain management and its performance instead of undertaking empirical investigations. Therefore this research attempts to capture the state of supply chain management in Chinese automotive companies based upon an empirical investigation and gives some suggestions for Chinese automotive industry future development.

The automotive industry was chosen for this research due to:

- Firstly, the automotive industry make a significant economic contribution to many countries, and is one of the largest manufacturing activities in the world (Sánchez and Pérez 2005).

- Secondly, as China is becoming one of the world's fastest growing markets for automotive manufacturing, the Chinese automotive industry has also become a hot topic researched by academics and practitioners (Wu 2005).

- Finally, the Chinese automotive industry is complex and different from the automotive industry in the West. The Chinese automotive industry is at an immature stage: the philosophy of customer-order-driven still needs to implemented. Rapid growth and uncertain demand information put manufacturers in a dilemma between inefficient production and over-capacity of production. Also some transport infrastructure such as port construction and supply chain facilities – for example train containers still need to be upgraded. All these factors make supply chain operations even more complex. In the future, Chinese automobile enterprises face not only competitors from domestic and international markets (Chen, Shi et al. 2005), but also need to pay attention to their performance for customers. Therefore this encourages China's automotive manufacturers to acquire further knowledge of supply chain management.

1.2 Research objectives

As mentioned earlier, much research has focused on Chinese automotive potential market development and vehicle technology development (Luo 2004), and there is a lack of research into supply chain practices and their performance in developing countries, in general and China in particular (Saad and Patel 2006). Also there have been many attempts to measure the performance at the operational level or focused on tangible factors, such as financial factors, but very little research has focused on the overall performance evaluation of supply chain management.

Therefore, the objective of this research is to evaluate supply chain management performance in the Chinese automotive industry based on several sample automotive companies. After exploring the performance of automotive supply chain management, the research points out the weakness of supply chain management in the automotive companies according to empirical investigation and experts' view. Also the research attempts to analyze the potential inhibitors for supply chain management in the automotive industry and provides some implications for supply chain management development in the future. Meanwhile, as most of the current performance measures fail to provide balanced and comprehensive frameworks in this context, the research attempts to propose a specific framework to measure supply chain management performance at strategic, operational and tactical levels. This proposed performance measurement framework integrates different participants' concern, balances financial and non-financial measures, and concerns a company's strategy and future development.

Following the objectives of the research, in this thesis, the areas listed below are included:

1) The research introduces supply chain management and supply chain management development. The research in particular introduces automotive supply chain management and different automotive supply chain procedures, including the

upstream supply chain, midstream supply chain, downstream supply chain and green supply chain.

2) The research outlines performance measurement definition, function and history. Also the research demonstrates performance measurement procedures and clarifies how performance measurements are applied in supply chain management.

3) The research demonstrates some well-known performance measurement methods which have been proposed by different researchers. Meanwhile after demonstrating each performance measurement method's advantages and disadvantages, an innovative performance framework consisting of the analytic hierarchy process (AHP) approach will be introduced to evaluate automotive supply chain management.

4) The research evaluates Chinese automotive supply chain performance from three perspectives: strategic perspective, operational perspective and tactical perspective. After evaluation, the research points out some weaknesses of Chinese automotive supply chain operations in terms of customer satisfaction, financial return, infrastructure investments and human resource management.

5) Finally the research develops some implications for automotive companies supply

chain management from performance evaluation and weaknesses analysis. These implications in particular include management perceptions, logistics standardization, supply chain integration and the reduction of the delivery time and supply chain cost.

The research fully presents the practice of supply chain management in the Chinese automotive industry. During the investigation, data collection was the main problem, and this includes:

Firstly, companies are reluctant to give internal data. Some participants are unwilling to spare time on sharing data or some data cannot to share due to business confidentiality.

Secondly, some data needed to be collected from different and disparate departments. For example - employee productivity data needed to be collected from financial departments and human resource departments, and this makes consistent data collection difficult.

Thirdly some empirical data is unavailable or impractical. Thus the research not only collected data from companies, but also from a variety of other ways to supplement and confirm data, including public papers, industrial reports, and some *automotive associations.*

The whole data collection and data analysis lasted for almost a year. The research has had to adjust measures and formulas in order to fairly evaluate supply chain performance while some data could be collected, such as a customer complaints ratio, which had to be interpreted as a customer satisfaction ratio, and some formulas of supply chain value measures had to be changed because the original data involved too many participants.

1.3 Structure of the thesis

The thesis consists of eight chapters, and a brief illustration of each chapter is provided in figure 1-1 below. The thesis is organized as follows:

Chapter 1 firstly briefly overviews the research background, then the research lists the research objectives and demonstrates a basic structure of the thesis.

In chapter 2, a review of the relevant literature to the research is undertaken. This chapter is composed of three main sections:

In the initial main section, the research overviews the literature review of supply chain management and automotive supply chain management. The research introduces supply chain management and its development, and the research emphasizes on relative literature on automotive supply chain and automotive supply chain management. Meanwhile the research briefly introduces the global automotive industry and then focuses on the Chinese automotive industry. Characteristics of the Chinese automotive industry and Chinese automotive market are mentioned in this part as well.

In the second main section of chapter 2, the research introduces performance measurement definition, history, procedure and application in the supply chain context. The research also overviews the various performance measurement methods and summarizes different performance methods' strengths and weaknesses. These performance methods include the balanced scorecard and performance of activity (POA) methods.

In the last part of chapter 2, the research explains different mathematical evaluation methods which can integrate with performance framework for the evaluation. These mathematical methods include: fuzzy comprehensive evaluation method and data envelopment analysis (DEA). After comparison of different evaluation mathematics' advantages and disadvantages in the context of assessing the performance of supply chain management for the Chinese automotive industry, the research finally selects Analytic Hierarchy Process (AHP) as a suitable mathematic used with the specific framework to evaluate the Chinese automotive supply chain performance. The Analytic Hierarchy Process application and procedure will be demonstrated in this part as well.

In order to come up with a suitable research approach and research strategy, Chapter 3 explains the research philosophy and relevant research approach. In this chapter, the research discusses three main philosophies, including positivism, interpretivism and realism. Also the research presents the research strategies that have been developed and utilized for evaluation: survey, case study and phenomenological. Meanwhile the research considers the research time horizon and demonstrates data collection methods, such as sampling, survey and interview, and observation and so on. Finally the research explains how to use tactics - triangulation methods to improve research reliability and validity.

The methodology of the Chinese automotive supply chain performance evaluation used in the thesis will be explained in chapter 4. The research firstly demonstrates the Analytic Hierarchy Process application and procedure to evaluate the Chinese automotive companies' supply chain performance and then the research develops a specific framework for the Chinese automotive companies. Also chapter 4 presents each performance metrics' explanations and formulas and proposes five steps to develop an AHP application for evaluation of supply chain performance measurement.

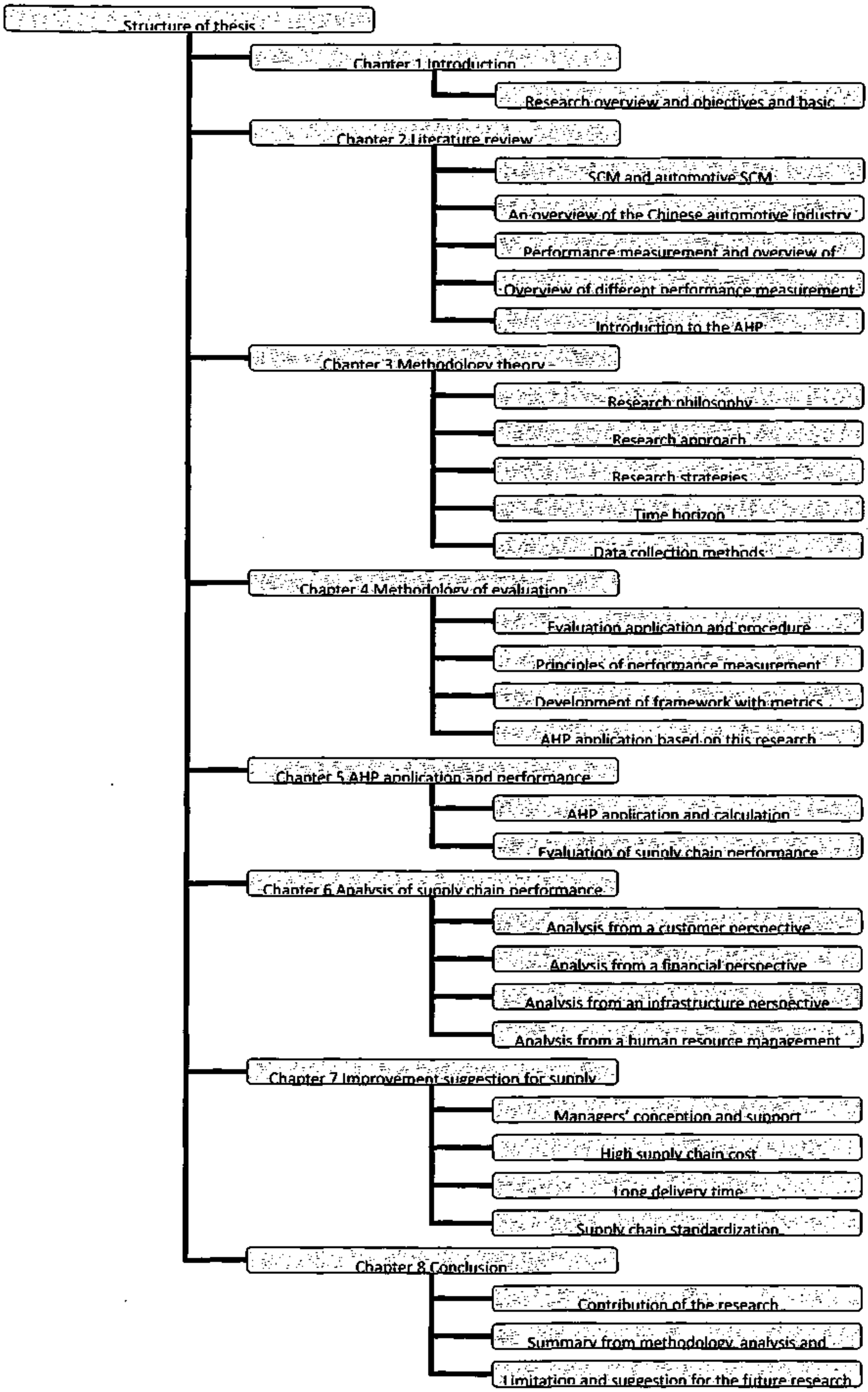
In chapter 5, the research firstly selects sample automotive companies for evaluation. Then the research calculates an expert scale on each metric and quantifies empirical data. The research facilitates the manipulation of the complex measurement system into a hierarchy of measures, and it then can be used with empirical data to assess the implementation of supply chain management. The research presents a clear view on performance measures with respect to each individual criterion for assessing the automotive companies. At the same time, the research presents evaluation results, and analyses seven automotive companies' performance individually based on their final scores.

Chapter 5 generally analyses automotive companies' supply chain performance through comparing and contrasting between companies. Chapter 6 further analyses seven automotive companies' performance in four sub-sections, namely from the customer perspective, financial perspective, infrastructure perspective and human resource management. This chapter highlights the key issues and challenges associated with supply chain management in the Chinese automotive industry.

After analysis of the evaluation findings, the research attempts to propose some improvements for automotive companies to enhance competitiveness in the future. In chapter 7 the research considers evaluation results and proposes improvements based on improving manager conception and support, increasing long time delivery, reducing high supply chain cost, and establishing logistics standardization.

In the last chapter, the research draws conclusions related to the performance measurement of supply chain in the Chinese automotive industry. In this part, the research firstly presents the contributions of the research and briefly overviews the research methodology. Then the research summarizes the main points from performance analysis and improvement suggestion with regard to supply chain operation. Finally the research points out limitations of the research and indicates future research on performance measurement of supply chain integration.

Figure 1- 1: Framework of the research



Chapter 2 Literature review

As discussed in the previous section, the thesis is divided into two parts: evaluation performance and improvement performance. The first part is evaluation of the performance of Chinesé automotive companies by using one of the performance evaluation methods that are available. The second part is an analysis of supply chain performance in the Chinese automotive industry and proposes some practical implications for supply chain operations which will lead to performance improvements.

In order to provide a literature foundation for the thesis's findings, this chapter will review these three main areas: in the first place, it is necessary to clarify the concept of supply chain management, automotive supply chain and automotive supply chain management. Also the Chinese automotive industry will be introduced in this section in order to provide the knowledge for the basic background.

Secondly, the thesis illustrates performance measurement definitions and a related literature review, including features such as performance measurement history, performance measurement procedure and performance measurement application in the supply chain context. In this part, the thesis also reviews and compares different performance measurement frameworks which have been proposed by a number of researchers.

In the final section, the thesis briefly demonstrates five different mathematical evaluation methods which include fuzzy comprehensive evaluation method and data envelopment analysis (ANN). The thesis compares the analytic hierarchy process with other evaluating methods and points out their strengths and drawbacks. Then the thesis places more emphasis on the analytic hierarchy process's advantages and applications, and also demonstrates the analytic hierarchy process's approach to measure supply chain performance.

2.1. Supply chain management

With increasing competition following market globalization and emphasis on customer orientation, more and more companies strive to achieve competitive advantage by using supply chain management (Gunasekaran, Patel et al. 2001; Webster 2002). The following section approaches the literature of supply chain management from three viewpoints - logistics and supply chain definition, supply chain management definition and supply chain management development.

2.1.1 From logistics to supply chain management

Logistics has grown from military uses during two World Wars. Cavinato (1982) accurately defined logistics as management of pre-production, in-production and post-production, in other words, logistics management involves purchasing (obtaining), producing, storage and distributing (Cox and Blackstone 2004). The Council of Supply Chain Management Professionals (CSCMP 2006) clearly clarified logistics as part of supply chain management. It is the process of planning, implementing and controlling the efficient, effective forward and reverse flow of storage of products, services and related information from the original point to consumption point for the purpose of satisfying customer requirements.

In the 1990s, with increasing competition in market globalization and emphasis on customer orientation (Gunasekaran, Patel et al. 2001; Webster 2002), many manufacturers strove to achieve competitive advantage by collaborating with their suppliers and retailers to improve product quality, reduce lead time and cost. Various new management philosophies evolved and emerged, such as supplier integration, partnerships, supply base management, supplier alliances, supply chain synchronization and so on (Londe and Masters 1994; Tan, Handfield et al. 1998; Tan, Lyman et al. 2002). The term supply chain management (SCM) is most widely used to describe this management philosophy. This new philosophy was to devote the company's limited resources to improve productivity and efficiency, creating value to achieve customer satisfaction (Chow, Madu et al. 2008). The Supply Chain Council has developed a cross-industry standard for supply chain management--the supply-chain operations reference model. Despite its popularity, there is no explicit description of its specific activities and practices, and how it impacts firm performance (Tan, Lyman et al. 2002).

2.1.2 Supply chain management definition

Various definitions of supply chain management have been provided in the past few decades. Davis (1993) defined a supply chain as a simple network of material processing with the following characteristics: supply, transformation and demand. Henry and Carman et al (2006) considered supply chain management should involve flows of material, information and finance in a complete value chain network which includes suppliers, manufactures, distributors and customers (Lau, Lee et al. 2006). The research summarized these definitions of supply chain as the network of autonomous or semi-autonomous business entities involved upstream and downstream even further expanded to re-cycling in different processes and activities. All entities on this network should focus on building collaboration on core operational issues in order to deliver value, either in the form of product, or service or combination of both, to its customers (Baatz 1995; Lin and Shaw 1998).

As mentioned before, in recent years research in supply chain management has been increasingly based on a network and process view. The supply chain is considered as one single entity linking major business functions and business processes within companies to enhance customer satisfaction (Spekman, Jr et al. 1998). The research agreed with Stewart (1995) and the Global Supply Chain Forum (GSCF 2006) described it as:

"Supply chain is the integration of key business processes which include plan, source, make and deliver, from end user through original suppliers that provide products, services and information that add value for customers and other stakeholders."

Stewart (1995) further complemented that supply chain management includes all logistics management activities, as well as coordination of planning and controlling process and activities, such as marketing sales, manufacturing operations, product design and finance and information technology (GSCF 2006). It is a hierarchical and strategic approach to planning supply chain demand, sourcing raw materials and components, making products and parts, tracking inventory and order fulfillment, and delivering to the customer and end user (Chow, Madu et al. 2008).

From the summary of definitions, the research proposes the definition of the supply chain as:

"Integrating suppliers, manufacturers and distribution centers to get the right products to the right place at the right time and in right condition. The major purpose of the supply chain is to improve product quality and delivery service, eliminate waste and satisfy customers. It has enabled firms to exploit supplier

strengths and technologies to support new product development (Morgan and Monczka 1995), and seamlessly integrate logistics functions with transportation partners to deliver directly to the ultimate customers. All the activities involved include sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer and upgrading information systems necessary to monitor all of these activities (Lummus and Vokurka 1999; Christopher and Towill 2001)."

2.1.3 Supply chain management development

The supply chain management phenomenon has received the attention of researchers and practitioners in various topics. The underlying philosophy of managing the supply chain has evolved to respond to business changing trends.

During the period from 1960 to 1975, corporations tended to have vertical structures, and relationship with suppliers were win-lose interactions. Manufacturing systems were focused on materials requirements planning (MRP), utilizing materials requirements, planning techniques, inventory logistics management and push and pull operation techniques for production systems (Poirier and Reiter 1996).

During the time from 1975 to 1990, manufacturers were still vertically aligned but several manufacturers started to realize the benefit of functional integration such as product design and manufacturing. Some manufacturers were involved in process mapping and analysis to evaluate their performance. Various quality philosophies, such as total quality management (TQM), and ISO Standards for quality measurement were initiated by many manufacturers. The Malcolm Baldrige Award and Shingo Prize for recognizing excellence in these and other quality initiatives were initiated. Manufacturing systems were focused on MRPII (Bruce 1997).

Since the 1990's, with increasing economic development and market competition, manufacturer structures are starting to align with processes. Strategic alliances among organizations have been growing. Manufacturing systems have been enhanced with information technology tools such as enterprise resource planning, distribution requirements planning, electronic commerce, product data management, collaborative engineering, etc (Aberdeen Group 1996). A number of factors have contributed to the design and implementation of an integrated system:

- Firstly, there has been a realization that better planning and management of complex interrelated systems, such as materials planning, inventory management, capacity planning, logistics, and production systems, enables manufacturers' productivity to be improved.

- Secondly, rapid development in information and communication technologies has stimulated strategic and tactical strategies essential to delivery of integrated systems growth. The availability of such systems has the potential of fundamentally influencing manufacturer integration issues.

2.2 Automotive supply chain and management

The research will present automotive supply chain management from two perspectives: automotive supply chain procedure and automotive supply chain management.

2.2.1 Automotive supply chain procedure

The automotive supply chain is complex and very different from other supply chains with respect to the supply chain process. The research divided the automotive supply chain into four stages: upstream supply chain, midstream supply chain, downstream supply chain and green supply chain. The following section will explore the automotive supply chain from these different aspects:

2.2.1.1 Upstream supply chain

As purchasers, automotive manufacturers procure components and materials (e.g. repair parts, operating tools. etc) from core suppliers or indirect materials suppliers. The activity of the upstream supply chain includes a company's supplier selection, supplier development and buyer-supplier relationship management (Mills et al., 2004).

In a traditional supply chain, manufacturers get order information from downstream and make decisions about their order quantities without regard to the actual inventory available upstream. If the upstream suppliers do not have enough inventories on hand to fill the orders, it often leads to overtime production or extra costs. Today, vehicle manufacturers are building long-term mutual commitments with suppliers who are willing to engage in continuous improvement and advanced technology, notably e-procurement[1], e-auctions[2] and e-business[3], to help the communication between upstream suppliers and manufacturers. This decreases automotive lead time, reduces inventory costs and stimulates integration between upstream and downstream supply chain (You and Zhu 2005).

2.2.1.2 Midstream supply chain

The midstream supply chain is a process where vehicle manufacturing, assembly and packing takes place. During past decades, the automotive manufacturing supply chain developed from three stages: mass production, 'leagile' manufacturing approaches and mass customization.

[1] E-procurement means electronic procurement
[2] E-auctions means electronic auctions
[3] E-business means electronic business

1) ***Stage of mass production***

The automotive industry was known as a typical industry adopting mass production. Early in this century, the Ford Motor Company achieved the most famous and one of the most strikingly successful example of mass production in the production of the Ford Model T for 19 years (Zhang and Chen 2006). However mass production appeared to decline in the 1960s. Several factors have contributed to this decline: technological innovation slowdown, lack of investment, overregulation, oil shocks and other external factors. In the 1980's and early 1990's, various approaches were attempted to respond to competition, such as total quality management (TQM) invented in the U.S and just-in-time production (JIT) invented in Japan. These management philosophies strengthen the organization's competitiveness by reducing waste and improving product quality and efficiency of production. However the success of these approaches is limited, as customers become more demanding and global competition becomes more intense, and these approaches failed to meet precisely specified customer requirements (Duguay, Landry et al. 1997).

2) ***Stage of leagile manufacturing***

The concept of 'leagile' supply chains was promulgated in the early 1990s in order to search flexible manufacturing system to satisfy specified customer needs (Naylor, Naim et al. 1999; Hoek 2000). The lean and agile manufacturing approaches were developed in the 1980's and were subsequently applied to automotive supply chain management. Christopher and Towill (2001) claimed the 'leagile' supply chain developed out of two concepts:

- *Lean manufacturing approach: it can be traced back to the Toyota production system (Womack and Jones 1996), it develops a value stream with focus on the reduction and elimination of waste including time within the factory (Ohno 1988).*
- *Agile manufacturing approach: Naylor and Naim et. Al (1999) developed the agile operation where minimal lead times to exploit profitable opportunities and service customer demand in a volatile market.*

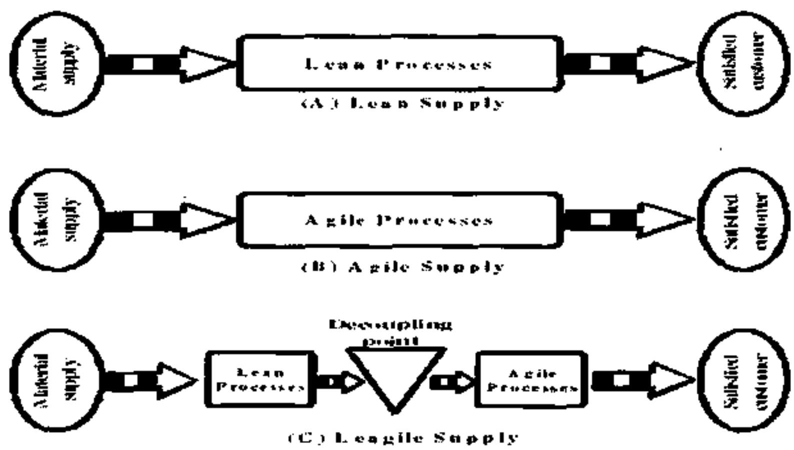
Naylor and Naim et. Al (1999) defined "leagile" as follows:

> *"**Leagile is** the combination of the lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the marketplace."*

> *"**The decoupling point** is the point in the material flow streams to which the customer's order penetrates. It is here where the order-driven and the forecast-driven activities meet. As a rule, the decoupling point coincides with an important stock point - in control terms a main stock point - from which the customer has to be supplied. (Hoekstra and Romme 1992)"*

The automotive supply chain is complex with at least five major echelons ranging from the hundreds of component suppliers through sub-assembly to final assembly line and to retailers and end customers. Vehicle manufacturers developed an integrated approach to materials planning at the supply chain level, supported by the simultaneous electric data interchange (EDI) transmission of requirements to all plants. To achieve leagility, the de-coupling point was located at the final assembly line, and customized vehicles only enter final assembly or configuration when the precise customer requirement is known (Christopher and Towill 2001; Bruce, Daly et al. 2004)(see figure 2-1).

Figure 2- 1: Three type of supply chain operations



Source: Christopher and Towill (2001)

3) ***Stage of customer-order-driven***

Waller (2003) pointed out traditionally, the primary aim of supply chain management for manufacturers is to optimize the availability of products, achieving a certain level of availability at a certain cost, in order to avoid stock out, where there is no product to meet the consumer's requirements, and the customer is obliged to choose an alternative product. Nowadays, in mature markets, Kuhn (2006) considered that increasingly automotive manufacturers are aiming for a mass customization and customer-order-driven strategy. Adopting customer-order-driven production can produce a number of benefits, including higher profits, low marketing costs and a significant increase in customer loyalty.

The transformation to customer-order-driven production is difficult, however most vehicle manufacturers work hard to transfer accurate customer order in a timely way in terms of cost, design, production, capacity and supply aspects (Zhang and Chen 2006), such as Volvo with its build-to-order (BTO) system (Eisenstein 2002), Ford with building vehicles to online orders (Warner and Bank 1999) and BMW with customer oriented sales and production (Holweg and Pil 2004).

2.2.1.3 Downstream supply chain

Johansson and McHugh et al.(1993) suggested that manufacturers extend after-sales service as a part of the supply chain, and the downstream supply chain process includes sale products and aftermarket operation. Vehicle manufacturers integrate their downstream value chains in order to increase customer satisfaction with regards to product quality, order cycle time, service level and cost. Furthermore, the downstream supply chain is located at the end of the chain with dealers and end customers, and it easily makes demand information more transparent (Lyons, Coleman et al. 2004). Mills et al (2004) stated that accurate visible real-time information, such as demand information and customer requirements for all activities in the supply chain, from procurement, transport, produce to store etc. can improve demand forecast and price fluctuations, stimulate the efficiency of upstream operations and result in faster system response time.

2.2.1.4 Green supply chain

The purpose of the green supply chain is to solve the dilemma between value seeking and lowering the environmental damage of business. Srivastara' view (2007) is advocated that defined green supply chain management as integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, and end-of-life management of the product after its useful life. Table 2-1 provides an example of detail of the scope of greening initiatives in the supply chain (Hoek 1999): First of all, the supply chain involves multiple participants. The first row lists a number of them, reaching as far as raw material suppliers and retailers. All of these participants play important roles in the green supply chain. During the initial production, the suppliers selected recycle and re-use materials. During midstream, environmental friendly materials are selected for assembly, dis-assembly and transportation, then in the downstream stages, participants take environmentally conscious, recycled products and materials after their life cycles. A set of performance measures related to these activities is identified and listed in the final row. Measurement such as transportation can be assessed in terms of capacity of transport equipment. A high degree of utilization is an indicator of transportation efficiency. The amount of useless space in a package can be measured in terms of handled volumes to indicate the effectiveness of the operation and the value of products returned.

Table 2-1: Participants, activities and evaluation of greening efforts throughout the supply chain

	Upstream	Midstream	Downstream
Participants	Raw materials suppliers Parts suppliers	Main suppliers Manufacturers	Wholesalers Importers/distributors Retailers
Green activities	Material selection Re-use of materials	Design for dis-assembly scrap, shred transportation	Packaging material Returns handling Returns shipment
Relation performance measures	Emission rates, Energy consumption	Volume of goods disassembled. Utilization of transport equipment	Amount of useless space in package. Volume selected for recycling

Source: Srivastara (2007)

The research summarized main factors significant in successful adoption of green supply chains can be categorized as:

1) Government

The scarcity of resources and degradation of environment has forced the Chinese government, both local and national to release environmental regulatory and tax policies. In order to control over-exploitation and over-consumption of resources, in 2001, the Chinese government has levied resource taxes and implemented quota-pricing systems for some resources such as water (Bai and Hidefumi 2002). Several organizations responded to this by applying green principles to their company, such as using environmentally friendly raw materials, reducing the usage of petroleum power, and using recycled paper for packaging (Zhu, Sarkis et al. 2006).

2) Market and competition

The second factor to adopt green supply chain is that companies are facing pressure from competitors and customers. Lo and Leung (2000) asserted that the development in consciousness of environmental problems such as global warming, toxic substance usage, and decreasing non-replenishable resources, has stimulated many Chinese consumers, especially younger consumers to develop environmental awareness and require an improved environmental performance.

In addition, Zhu and Geng (2001) indicated valuable analysis: because Chinese automotive companies failed to provide materials and products that meet these foreign enterprises' environmental requirements, most joint ventures or foreign direct investment (FDI) companies in China purchase key raw materials and components mainly from their home countries, or from upstream suppliers in their supply chains already operating in China. Chinese automotive companies therefore have to face pressures from green barriers from joint venture company competition.

In order to satisfy customers and survive in the market, companies have to raise ecological efficiency by balancing economic benefits and lowering environmental risks and impacts (Zhu, Sarkis et al. 2006).

3) Within the company

The two drivers mentioned earlier are from external factors. Sometimes a driver is from the company itself. Numerous studies support that adopting a green supply chain can bring benefits in reducing cost, increasing operational efficiency, eliminating material waste and environment pollution, and generating brand reputation (Jorgensen 2005). In terms of human resources, it also enhances employee morale from some green programs such as wellness programs, and an ergonomic work environment (Gunther 2006).

2.2.2 Automotive supply chain management

After clarifying the four processes of the automotive supply chain, in this sector, the automotive supply chain management characteristics and definition will be presented.

Automotive supply chain management is defined in this research as:

> *"Automotive supply chain should considered as a single entity to deliver value, combination of product and service to satisfy customers. Supply chain management links all of the partners including departments in organizations and the external partners including suppliers, detailer, carriers, third-party companies and information system providers(Gong and Wu 2008). All the activities including, such as raw materials procurement, manufacturing and assembly, inventory deployment and management, transportation management, packaging and material handling and distribution products and so on* (Li, Wang et al. 2007)"

Rubesch and Banomyong (2005) described that the complete automotive supply chain process includes the following processes:

Procurement and Press workshop

Manufacturers send orders to suppliers, then materials or components are delivered to the manufacturers, and put on large and medium mechanical press production line for uncoiling, blanking, painting and piling.

Welding workshop

Different automotive manufacturers may have different production scales. In general, for a total production capacity of 80,000 units, the welding workshop has around ten production lines, one car adjusting line; and is equipped with one conveyor line, and automatic welding-machines, welding robots. These operations include forming body panels, welding vehicle frames and putting in other components, such as engines, seats, instrument panels and various other electrical, mechanical and decorative items (Rubesch and Banomyong 2005).

Painting workshop

The painting production line consists of numerous sets of production equipment. The painting technology is composed of seven parts, including pre-treatment line, sealing glue line, intermediate painting line, colouring line, finish painting line, adjusting line, and auxiliary line.

Assembling workshop

The assembling workshop has a long general assembly line, composed of push-bar hanging line, common hanging line, plate ground line, and sub-assembling lines. In this process, the vehicle will be equipped with an automatic guided lifting (AGV) system, for engine, chassis, rear axle, and fuel tank correspondingly. After assembly, the vehicle is put on the end of the testing line for security and function test before delivery to customers.

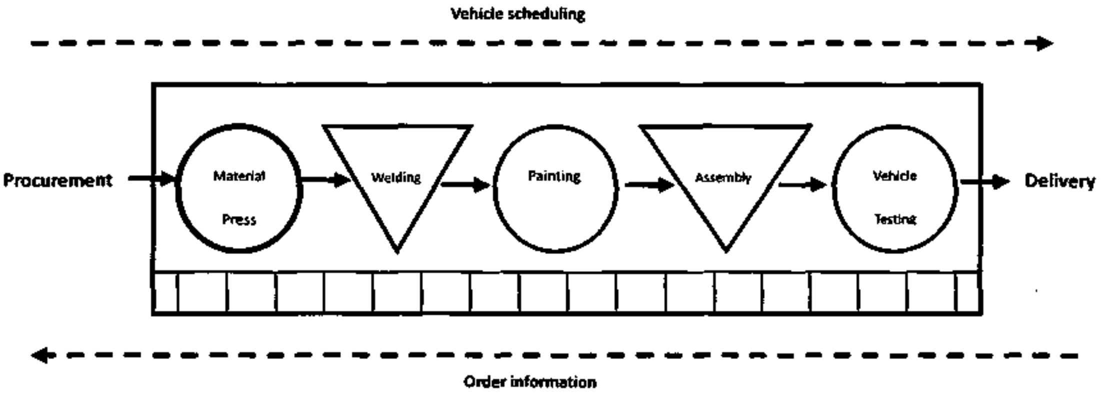
Vehicle delivery

After vehicle assembly, car manufacturers outsource the delivery of new vehicles. Typically, a third party logistics company is used for a number of functions, such as pre-delivery inspection (PDI), delivery vehicle, and late-configuration of some parts of the vehicle for customer specific requirements, such as decals, fitting of radios or alarms and other aspects (Holweg and Miemczyk 2002).

During manufacturing, each vehicle contains a data chip, recording the type of vehicle and dealer and customer's information. With this data, the company can easily control each step of its vehicle manufacturing process from assembly to distribution and after-sale service, and thus reduce production time and cost.

Operationally, the automotive supply chain is partitioned into several key stages ranging from component procurement, raw materials storage with different members, vehicle welding, vehicle trim and painting, vehicle assembly, to vehicle testing and final delivery. Totally, the supply chain cycle time typically on average is 143 hours from raw materials to vehicle assembly, and analysis has showed that it includes a value-adding time of 12 hours, and 8.9 hours of non-value-adding time which is skewed towards the upstream processes, distribution and in particular, to raw material storage (Lyons, Coleman et al. 2004). Finally, the research summarizes the process outlined in figure 2-2 and shows the whole supply chain of manufacturing a vehicle as follows:

Figure 2-2: Vehicle manufacturing process



Source: Lyons and Coleman (2004)

Finally, the research summarized that the automotive supply chain has these particular characteristics:

1) Each vehicle is composed of 20,000 auto parts. Manufacturers normally have various vehicle models, and each needs a large variety of auto parts. The supply chain starts from receiving the order from customers until finishing the delivery. This process is considerably more complicated than most other industries (Gong and Wu 2008).

2) Automotive manufacturers have upstream participants-suppliers and downstream participant-dealers. For German luxury carmaker BMW's joint venture company in China, there are a total of 150 local spare parts suppliers and more than 100 dealers by the end of 2008. Suppliers and dealers are located domestically or

abroad and the network is a massive entity that needs to be managed (Sun 2009). Thus manufacturers located in the middle of the supply chain play an important role in supporting the whole supply chain cooperation and development.

3) Under heavy competition, manufacturers have to keep pace with customer demand in designing the model and vehicle production. For BMW's new vehicle series X5, the manufacturers provided 8 different models, 12 different colours and 19 different engine sizes, and more than 60 other specific needs for customers. Customer-order-driven production has been driving manufacturers to do more on efficient supply chain management, such as supply chain integration, information system development, and partner relationship management and so on (Sun 2009).

Since uncertainty on customer demand in the current competitive environment, the leagile supply chain has emerged to cope with uncertainty and market volatility (Turner and Williams 2005). Vorst and Dijk et al.(2001) considered agility of a supply chain is driven by customer demand which is characterized by uncertainty. As a result, automotive companies delayed vehicle configuration as long as possible to the moment when specific requirements from customers are clear. The automotive supply chain has thus gained the greatest possible flexibility in responding to customer demands, and vehicle assembly and delivery are also customized. Tu and Xu (2006) suggested that the principle of the leagile supply chain should based on seeking design automotive and manufacturing components using a common platform, but final painting and assembly does not take place until customer requirements are known.

2.3 An overview of the Chinese automotive industry

This section will review the global automotive industry first, then the thesis will review the Chinese automotive industry including its automotive characteristics and the provision of government plans and support. Finally the research will introduce the Chinese automotive market.

2.3.1 Review of the global automotive industry

In 2007, global vehicle production reached a peak at 73.3 million, increasing 5.8% compared with 2006 (Organisation Internationale des Constructeurs d' Automobiles (OICA) Statistics 2009). However in 2008, it was affected by the global financial crisis, and the global vehicle production slightly decreased 3.7% at 70.5 million units. In 2009, global vehicle production further decreased 13.5% and dropped to 61 million units (Schmitt 2010).

According to Schmitt's (2010) report (see table 2-2), in 2009 most countries sales are still in decline, including sales in the USA which amounted to only 10.43 million, reducing 2.77 million units. Also, the economic downturn affected Japanese sales, dropping to less than 5 million, the lowest point since 1978. Sales in Spain also fell to the lowest point at 0.95 million in recent 15 years (ZhengJiang Auto News 2010). The reasons why the global automotive industry is depressed are: substantial rising of petrol price and the global financial crisis. In addition World crude oil demand growth and the decline in petroleum reserves evoked the 2003 to 2008 energy crisis, and consumers were encouraged to choose low petrol consumption vehicles (Arabia 2006). Meanwhile the 2008 credit crisis placed pressure on vehicle raw materials which contributed heavily to the sales steep decline (Vlasic and Bunkley 2008).

Even though the global automotive market is depressed in 2009, however some countries still have exhibited good sales, such as China where sales increased 45.5%, reaching 13.64 million units. The reasons for high sales in the Chinese automotive market are: firstly because of high economic growth. In 2009, economic growth accelerated to 8.7% over a year (USA Today News 2010). Secondly the vehicle sales rise is due to the government stimulating vehicle market demand. These measures included cuts in sales tax for small cars (BBC News 2010). In 2009, Germany also achieved good sales at 3.81 million units because of government financial subsidy for the vehicle trade. Korea sales have grown 21% relying on high vehicle export volume (Sina Analysis 2010).

Table 2-2 Worldwide vehicle sales in 2009

China	13.64[4]	↑45.5%	American	10.43	↓21.2%
Germany	3.81	↑23.2%	Spain	0.95	↓17.9%
Korea	4.05	↑21%	Sweden	0.21	↓16%
India	1.43	↑18.7	Canada	1.46	↓10.7%
Brazil	0.31	↑11.35%	Japan	4.61	↓9.3%
France	2.26	↑10.7%	Australia	0.94	↓7.4%
			England	1.995	↓6.4
			Italy	2.16	↓0.17

Source: Schmitt (2010)

2.3.2 Characteristics of the Chinese automotive industry

The Chinese automotive industry started in the 1950s, but rapid modernization and development began in the 1990s with the aid of foreign leading automotive manufacturers' direct investment and technology support. Since joining the World Trade Organization (WTO) in 2002, China has become both the fastest growing vehicle market and the fastest growing vehicle producer (2006). Vehicle output and sales have grown from less than two million vehicles annually before 2000 to over 9 million vehicles in 2008 (Table 2-3) (Appendix 3) (Mei 2008). Since January 2009, as tax cuts on small cars and government vehicle subsidies in rural areas took effect, China took the lead over the USA becoming the world's biggest auto market (News Analysis 2009).

[4] Unit: One million units

Table 2-3: Auto production and sales data from 2006-2009

	Auto Produce	growth ratio	Auto sales	growth ratio
2006	727.97	↑27.32%	721.60	↑25.13%
2007	888.24	↑22.02%	879.15	↑21.84%
2008	934.51	↑ 5.21%	938.05	↑ 6.7%
2009	1379.04	↑44.5%	1364.48	↑45.5%

Source: The National Report on Automotive Industry (2009)

In general, the Chinese automotive industry has these characteristics (Han 2009; Zheng 2009):

1) Chinese automotive industry relies seriously on foreign investment

At present, there are 355 vehicle brands available on the market, including commercial vehicles such as trucks and buses, however Chinese own brands only accounted for 69%, foreign brands accounted for 31%. In more than 100 brands of sedans, domestic vehicle brands accounted for only 33, and joint venture automotive companies accounted for 87 % of Chinese sedan market share.

2) Economic vehicle has become the highlight of market demand

Due to the increasing cost of petrol and the development of environmental awareness, the economic vehicle with low emission and low petrol consumption has become popular, and economic vehicles with an emission volume of less than 1.6 liter took a larger market share. In accordance with the statistics from the China Association of Automobile Manufacturers, in 2008, the total sales of sedans rose to

5.04 million, taking up 74.7% of passenger vehicle sales (Bai and Chen 2009).

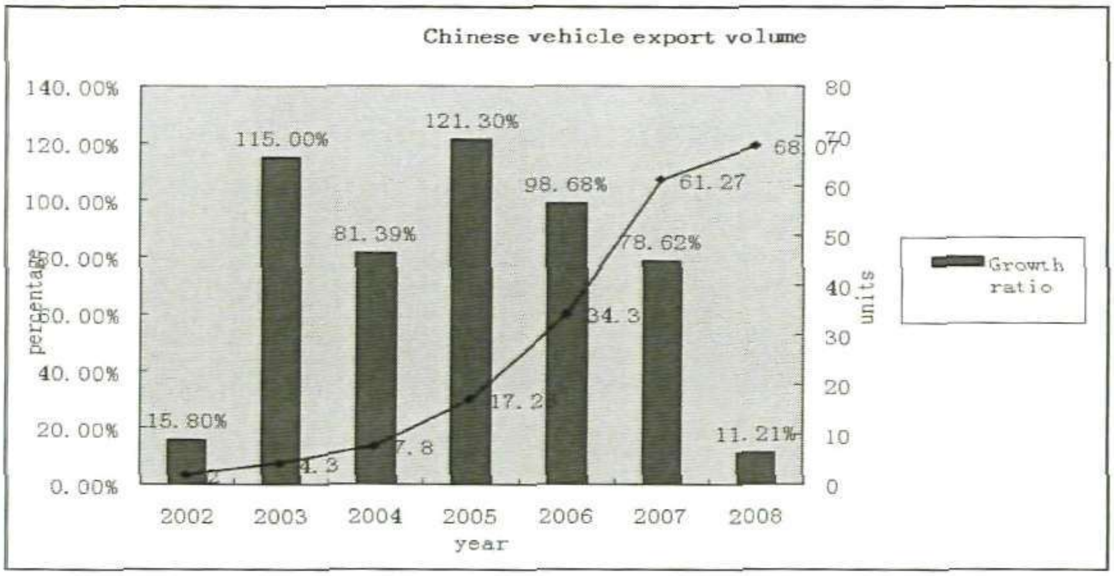
3) Commercial market is depressed

As passenger vehicles retained high demand for the market, commercial vehicles are general relatively depressed. In 2008, commercial vehicles sold only represented 2.62 million units, taking up less than 40% of the passenger vehicle market share.

4) High vehicle production but low vehicle export

As China's automotive industry maintains high growth, vehicle exports have played a very small role so far. In 2008, China's exports of vehicles were 0.68 million units, ranking in the top eight, far behind Japan, France and Germany which exported more than 4 million units (see figure 2-3) (Xian and Wu 2008). Commercial vehicles, such as light and heavy trucks, are slightly higher than passenger cars, which accounted for approximately 65 % of total export vehicle units. The vast majority of Chinese auto exports are unlikely to go to Europe or the United States, but rather to countries nearer to China geographically, mostly destinations including Russia, south-east Asia, Africa, Latin America and the Middle East (Mann 2008).

Figure 2-3: Chinese vehicle export volume and growth ratio from 2002 to 2008



Source: Xian and Wu (2008) and Mann (2008)

2.3.3 Government plan and support

In order to create an internationally competitive vehicle, the major government efforts for the Chinese automotive industry include (Yang and Pillsbury 2007; Aervitz 2008; Chao, Wang et al. 2009; Li and Shi 2009; Ping and King 2009):

1) Promote the consumption of automotives

In 2008, auto sales growth shrank with an increase of just 6.7 percent, the first single-digit expansion since 1999 in an automotive market which is used to growth rates of more than 20 percent. As the global economy slowed down, the Chinese government has introduced a series of economic stimulus policies in order to boost the confidence of the automotive industry, and also to mobilize the enthusiasm of consumers:

(i) Reasonable taxation system reform

In April 2008, the Chinese government established a tax reform which including cutting purchasing tax in half at 5%, down from 10%, a decrease of petrol tax for energy-saving small engined vehicles and reduced consumption tax for consumers (Liu 2009).

(ii) Provide financial subsidies

The Chinese government also introduced a new series of policies to boost automotive consumption. The government offered subsidies for countryside people purchasing new cars and encouraged old-car owners to scrap their old vehicles for brand new ones by providing subsidies for trade-in (Jiang, Guo et al. 2008).

(iii) Financial support for the second-hand auto market

The Chinese government further developed a support system for second-hand auto sales, including simplifying second hand auto trade procedures, providing auto trade information, and ensuring second hand after-sales service. Also, the Chinese government offered financial subsidies for the second-hand vehicle trade (Yan and Bin 2009).

2) Support automotive industry research and development

The Chinese government encouraged domestic vehicle manufacturers to develop autonomous research capabilities through joint ventures with foreign partners. Almost all large international automobile companies have invested in China, such as General Motors (GM), Toyota Motor Corporation (TMC), Ford and Volkswagen. The government allows a foreign partner to have more than 50% ownership in a joint venture company, such as in the case of Honda Automobile (China) Co Ltd in the Guangzhou Development Zone. Honda was allowed to have 65% ownership in a joint venture, which was unprecedented. Recently, legislation came into force permitting foreign companies in the automotive industry to have up to 70% of shares if they export vehicles (Hui 2009).

The Chinese government believes electric battery operated cars will take a major marketing role in the future. In 2009, Auto Industry Planning continues the trend of encouraging auto manufacturers to build up their own research and development capability particularly on energy saving and environmentally friendly technologies (Ping and King 2009). The Chinese government offered tax subsidies to automotive companies and local government agencies to purchase electric vehicles to stimulate the electric vehicle development.

3) Restructure and consolidate the automotive industry

From 2001-2011, the Chinese government aims to restructure and consolidate the automotive industry--from 180 individual manufacturers to two or three large automotive groups and from several hundred parts suppliers to five to ten large supplier groups. The ultimate goal of automotive-industry consolidation is to create two or three globally competitive car producers which produce more than 2 million vehicles a year. In addition there will likely be a further 4 or 5 automotive companies with an annual production volume of more than 1 million vehicles.

Nowadays, the Chinese government encourages FAW, Dong Feng, Shanghai Automotive and Chang'an Automotive to merge and acquire smaller automotive companies across the country, whereas BAIC (Beijing Automotive Industry Corporation), Guangzhou Automobile, Chery and CNHTC5 are encouraged to conduct automotive trade on a regional market.

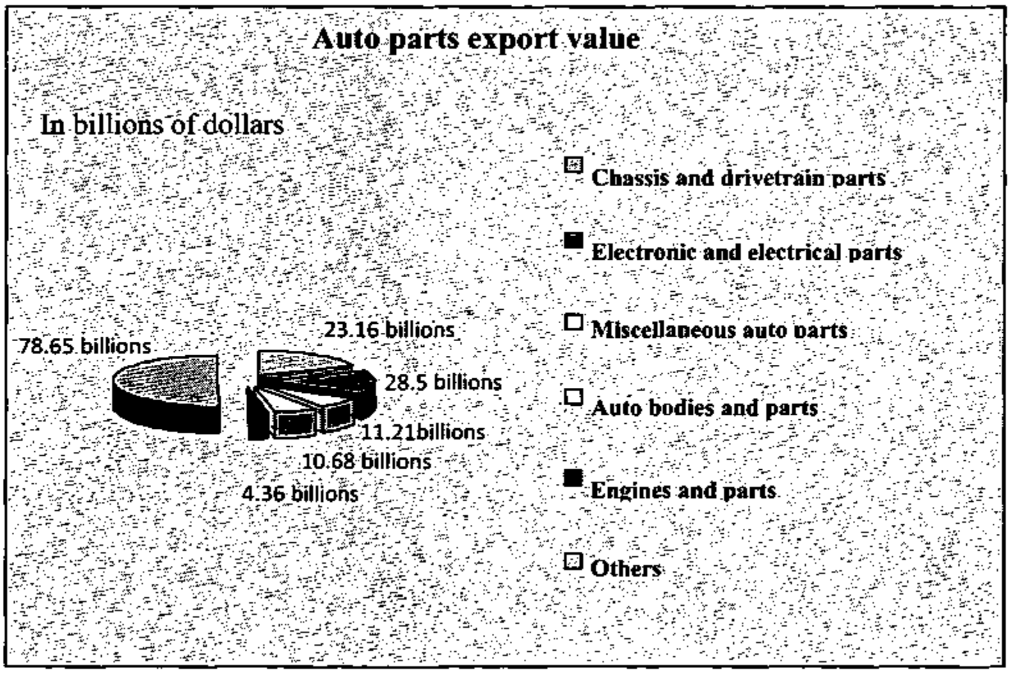
4) Encourage vehicle exports

China exports a broad range of vehicles and auto parts (Bradsher 2008), however the high technical content of vehicle and auto components such as chassis and electronic

[5] The headquarters of China National Heavy Duty Truck Group Co., Ltd. (CNHTC) is located in Jinan city, Shandong province. It is famous for developing and manufacturing the first heavy duty truck -- "HUANGHE" brand vehicle model. A company successful introduced the "STEYR" heavy duty truck production project, and become a leading company in the heavy-duty truck industry. Nowadays a company setting up a joint venture with VOLVO to manufacture the heavy duty trucks with up-to-date international level.

and electrical parts only account for 18.3% of the total value of China's vehicle exports. The big share of these products are low value-added vehicle and parts with low technical content (See figure 2-4) (Ally 2008). In order to lift the value of vehicle and auto parts, the government supports vehicle manufacturers engaging in technological research and development (R&D), and shifting from technology dependency on foreign partners in joint ventures toward independent production (Mao, Zhang et al. 2008).

Figure 2-4: Chinese auto parts export value in 2007



Source: Automotive News (2008)

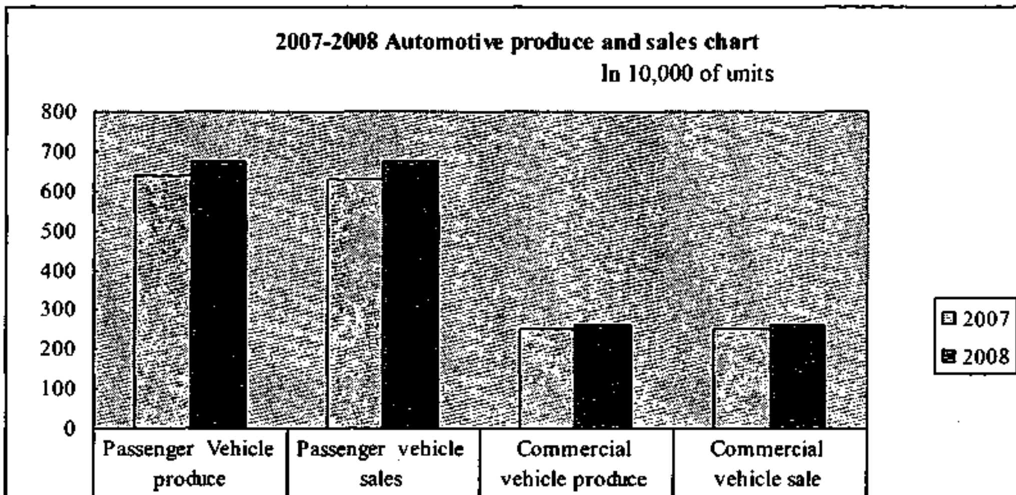
2.3.4 The Chinese automotive market introduction

In 2007, the Chinese automotive industry had showed strong sales and revenue growth. In a total output of nearly eight million vehicles, China has sold approximately 2.49

million commercial cars combined with truck and bus production and approximately 6.29 million passenger cars, representing a 22.02% increase over 2006 (See figure 2-5) (appendix 5) (Li 2007).

According to the State Express report (Xinhua News 2007), much of Chinese automotive industry's growth has been contributed by increasing demand for passenger cars which now account for more than two-thirds of China's production, an increase of 22.1% compared with 2006. Meanwhile, sedans still dominate in passenger cars, with the sales reaching 4.7 million units, accounting for 74.6% of the whole passenger car market while sports utility vehicle (SUV) sell approximately 26,200 units, rising to 15.77% and Mini Passenger Vans (MPV) to more than 3.2% of market share, rising 14.89% to reach 20,400 units (See figure 2-6 and figure 2-7) (Automotive Industry Report 2008).

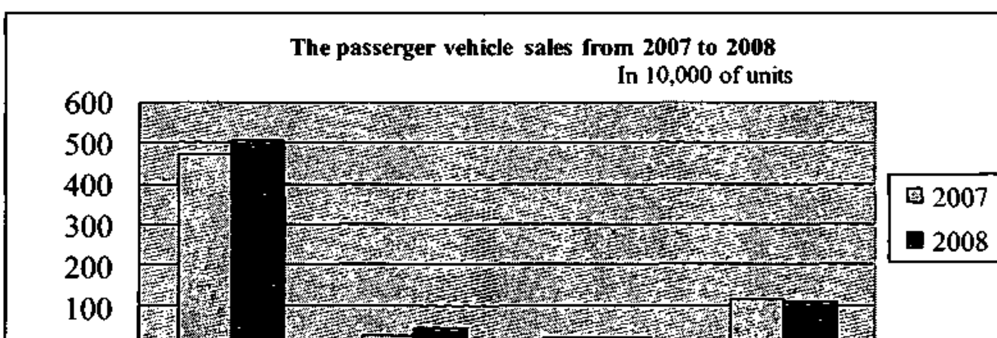
Figure 2-5: 2007 -2008 automotive production and sales chart



	Passenger Vehicle produce	Passenger vehicle sales	Commercial vehicle produce	Commercial vehicle sale
2007	638.11	629.75	250.13	249.4
2008	673.77	675.56	260.74	262.49

Source: The National Report on Automotive Industry (2009)

Figure 2-6: Passenger vehicle sales from 2007-2008



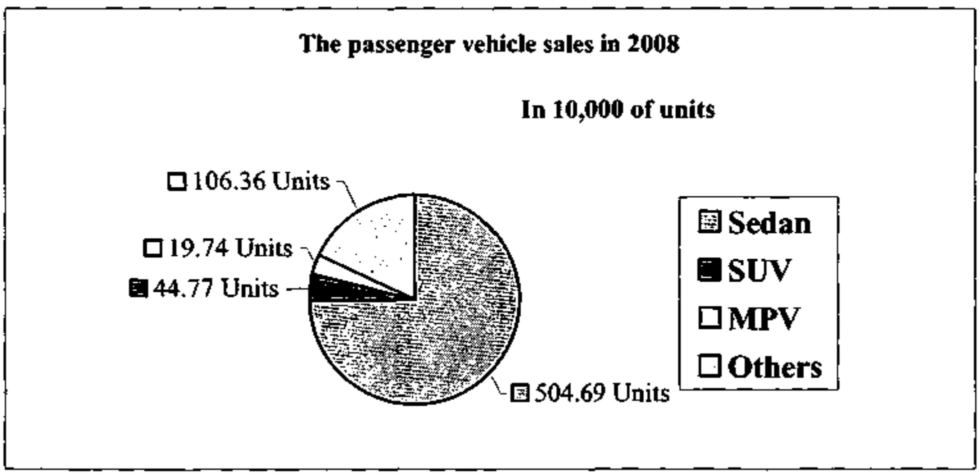
	Sedan	SUV	MPV	Others
2007	470	26.2	20.4	113.4
2008	504.69	44.77	19.74	106.36

Source: Automotive Industry Report (2009)

In 2008, the total amount of China's automobile production and sales reached a new high, with automotive output of 9.35 million and automotive sales of 9.38 million, while passenger vehicle production and sales are 6.74 million units and 6.76 million units, and commercial vehicle production and sales 2.61 million units and 2.62 million units (See figure 2-5).

By contrast, in 2008 the vehicle output and sales growth slowed down because of the global financial crisis and China's economic slowdown. The automotive output increased 5.21%, dropping down 16.81% compared with the previous year, the automotive sales increased 6.70%, falling 15.14% compared with 2007. Nevertheless, in 2008 China's vehicle consumption still exceeds Japan (Fu, Ru et al. 2009).

Figure 2-7: Passenger vehicle sales in 2008



Source: The National Report on Automotive Industry (2009)

In 2009, as automotive sales slowed with global economic and job concerns, the Chinese government introduced an economic stimulus plan, such as financial subsidies and taxation reforms. Since February, China has become the biggest automotive market in the world. According to the China Association of Automobile Manufacturer's statement, in 2009 the overall vehicle sales rose 45.5% to 13.64 million, while China's passenger automotive sales took 75.7% of the market share rising to 10.33 million units which included sport-utility vehicle, multi-Purpose Vehicles and other passenger vehicles (Ying 2009).

2.4 Performance measurement

Operations performance measurement can provide important feedback information to enable managers to monitor performance, reveal progress, enhance motivation and communication, and diagnose problems (Rolstandas 1995; Waggoner, Neely et al. 1999). Over the last few years, performance measurement applied in supply chain management has become more important. Lohman and Fortuin (2004) noted the main reason is: companies start seeking ways to improve operational performance through a better integration of operations across subsequent echelons and separate functions in the value chain. However many critical drawbacks are clear from existing performance measures. With the aim to fill this gap, the research attempts to propose an innovative performance measurement for the Chinese automotive industry.

This part is organized as follows: the first section is the introductory section to performance measurement. The second section is a related literature review of performance measurement in terms of function, history and process. In section three, the research will focus on performance measurement in the supply chain context.

2.4.1 What is performance measurement?

With a massive literature on performance measurement, Neely et. al (1995) clearly clarified the variety of definitions that exist as stated below:

- *A performance measure can be defined as a metric used to quantify the efficiency and/or effectiveness of an action.*
- *Performance measurement (PM) can be defined as the process of quantifying the efficiency and effectiveness of action.*
- *A performance measurement system (PMS) can be defined as the set of metrics used to quantify both the efficiency and effectiveness of actions.*

Lohman et al (2004) further commented that a performance metric also is called performance indicator (PI). Performance measurement is a procedure that integrates PIs with software and databases to evaluate operational performance in a consistent and complete way.

Neely et. al (2005) and Beamon's (1996; 1999) view has been taken for this research on dividing supply chain performance measures into two: single performance measures and joint performance measures.

- **Single performance measures**

From the literature review on manufacturing strategy, the key dimensions of manufacturing's performance can be defined broadly in terms of quality, delivery speed, delivery reliability, and price (cost) (Leong, Snyder et al. 1990; Neely, Gregory et al. 2005). Table 2-4 shows the multiple dimensions of single supply chain performance measures. Taking an example, practitioners measure manufacturing' performance in terms of quality, measures selected from the perspectives of product features, reliability, technical, and service and so on. These questions include: whether products are qualified and safe to use? Are customers satisfied with products and service? How to improve products on function and aesthetics?

Single performance measures are commonly used by many researchers and practitioners because of their simplicity. However single performance measures fail to provide balanced measures at various points along with the manufacturing process. Also single performance measures evaluate performance only on one characteristic of an objective, and measures are not based on the company's strategy and can not provide guidelines for operational action.

Table 2-4: The multiple dimensions of quality, time, cost and flexibility

Quality	Time	Flexibility	Cost
Features Reliability Technical Durability Service ability Aesthetics Humanity Value	Manufacturing lead time Rate of production introduction Deliver lead time Due-date performance Frequency of delivery	Material quality Output quality New product Modify product Deliver ability Product volume	Manufacturing cost Value added Selling price Operational cost Service cost

Source: Neely, Gregory and Platts. K (2005)

- **Joint performance measures**

Joint supply chain performance measures mean adopting a number of various performance measures as an entity. A large number of different types of performance measurement are available making measure selection difficult, and so Beamon (1999) proposed useful suggestions for companies creating measurement systems that they should base their decision on these questions: what to measure? How are multiple individual measures integrated into a measurement system? How and when are measures re-evaluated?

Stainer (1997) recommended performance measurement should be based on the characteristics of a manufacturer's operations, whatever performance measure or set of performance measures are used to determine the efficiency and effectiveness of an existing operational system, or compare competing alternative systems. Stoop and Bertrand (1997) suggested that joint performance measurement provides necessary information about management progress feedback for decision makers, and diagnosing problems supports companies to set up appropriate parameters to monitor and guide performance improvements.

2.4.2 Performance measurement history

Ghalayini and Noble's (1996) claim on dividing performance measurement development into two main phases was supported:

The *first* phase began in the late 1880s and went through to the 1980s. In this phase, performance measurements primarily emphasized management accounting systems. These financial measures include company profit return on investment and productivity and so on.

The *second* phase started in the late 1980s as a result of global economic integration. Companies began to seek higher-quality products with lower costs and more variety. In order to regain a competitive advantage, companies not only shifted their strategic priorities from low-cost production to quality, flexibility, short lead time and dependable delivery, but also implemented philosophies of new technologies and manufacturing management, such as computer integrated manufacturing (CIM), flexible manufacturing systems (FMS), just-in-time (JIT), optimized production technology (OPT) and total quality management (TQM) and so on (Neely 2003).

The globalization of business also has made significant impact on supply chain management strategy and performance. The trend has been for companies to source globally and therefore they have to invest in supply chain facilities and software, and shorter manufacturing and delivery lead times, and constantly adjust supply chain strategies to meet new requirements from customers.

As shown in table 2-5, traditional performance measures have many limitations that make them less applicable in today's competitive market. Such as the fact that they are based on financial measures and only evaluate middle and high managers, they are not related to a company's strategy, they are inflexible, expensive and contradict continuous improvement. Therefore in response to the need for new challenges, various new performance measurement approaches that should be used to drive improvement have been developed and presented by many researchers and have been implemented by many companies (Ghalayini and Noble 1996).

Table 2-5: Comparisons between traditional and non-traditional PM

Traditional performance measures	Non-traditional performance measures
Based on traditional accounting system	Based on company strategy
Mainly financial measures	Mainly non-financial measures
Intended for middle and high managers	Intended for all employees
Lagging metrics (weekly or monthly)	On-time metrics (hourly, or daily)
Difficult, confusing and misleading	Simple, accurate and easy to use
Lead to employee frustration	Lead to employee satisfaction
Neglected at the shopfloor	Frequently used at the shopfloor
Have a fixed format	Have no fixed format (depends on needs)
Do not vary between locations	Vary between locations
Do not change over time	Change over time as the need change
Intended mainly for monitoring	Intended to improve performance
Not applicable for JIT, TQM, etc.	Applicable
Hinders continuous improvement	Help in achieving continuous improvement

Adapted from Ghalayini (1996)

2.4.3 Performance measurement procedure

Several researchers, including Bourne and Lohman, indicated useful suggestions on performance measurement procedure. They asserted the procedure of performance measurement may conceptually be separated into phases of design, implementation, and use (Bourne, Mills et al. 2000; Lohman, Fortuin et al. 2004):

- The design phase is about defining manufacturers' strategic objectives and selecting performance measures.

- In the implementation phase, procedures translate both financial and non-financial measures into specific objectives that provide guidelines for operational action for middle and lower management.

- After collecting and processing the data that enables the measurements to be made regularly, in the use phase, managers review the measurement results to assess whether operations are qualified and whether the strategy is successfully implemented.

The appropriate measures are derived from several rounds to review and revise. Review and revise processes imply that the measured objective may change, the definition of measures may change, and a measure may even be deleted or replaced (Neely, Gregory et al. 1995). Also the availability of data is one of the considerations in the design process, and there is more attention on updating performance measures once they have been implemented. Kaplan and Norton (1992) emphasize using documents, interviews, and executive workshops for gathering information and building consensus.

2.4.4 Performance measurement in the supply chain context

Many companies are trying to improve supply chain performance measurement. Gunasekaran et. al (2001) and Tsang et. al's (1999) made valuable comments on the flaws of performance measurement in the supply chain context, stated as below:

1) *Performance measurements are not connected with the company's strategy.* Several functional or regional departments are each responsible for one aspect or one part of the supply chain and only top management is responsible for the total performance measurement results (Gunasekaran, Patel et al. 2001).

2) *Lack of balanced approaches for performance measurement.* Kaplan and Norton (1992) clearly point out, while some researchers and managers have concentrated on financial performance measures, others have concentrated on operational measures, thus an inequality can lead to metrics that cannot be presented in a clear picture for organizational performance. Maskell (1991) suggested that financial performance measurements are important for strategic decision and non-financial measures are important for controlling manufacturing and distribution operations. Thus Maskell proposed a useful suggestion as building a balanced manufacturing performance measurement integrates multiple measures, such as internal and external, financial and non-financial measures, performance drivers and outcome measures.

3) *Lack of a system viewing the supply chain as one entity and measurement process across the whole.* Chan and Qi's view is advocated (2003) that performance

measurement need to define supply chain measure performance as a whole and drilldown to different measures on different aspects and different participants, including suppliers, detailer and customers.

4) *Lack of a clear distinction between metrics at strategic, tactical, and operational levels* (Gunasekaran, Patel et al. 2001). *Gunnasekaran and Patel (2001)* noted metrics are used in performance measurement to influence the decisions to be made at strategic, tactical, and operational levels. However, manufacturers fail to classify operational levels for supply chain management. Thus the research considers classification of metrics should based on these three levels, and each metric can be assigned to a level where it would be most appropriate. For example, in dealing with operational measurement, one of most suitable metrics can be accessed from capacity utilization, where day-to-day capacity utilization rates can be measured and monitored.

It is clear that for effective management in a supply chain, measurement objectives must consider the overall supply chain goals and the metrics to be used. The measurement frameworks should represent a balanced approach and be classified at strategic, tactical and operational levels, and integrated various financial and non-financial measures, as well.

2.5 Overview of different performance methods

The appropriate design of performance measurement for modern manufacturing companies is an increasing concern for both academics and practitioners. Many authors have proposed various performance frameworks. This research will review literature on a number of the most significant supply chain performance measurements and metrics.

2.5.1 Balanced scorecard

The balanced scorecard (BSC) was originally proposed by Kaplan and Norton (Kaplan and Norton 1992) and is built on four perspectives and integrated performance metrics for strategic, operational and financial levels (see Figure 2-8):

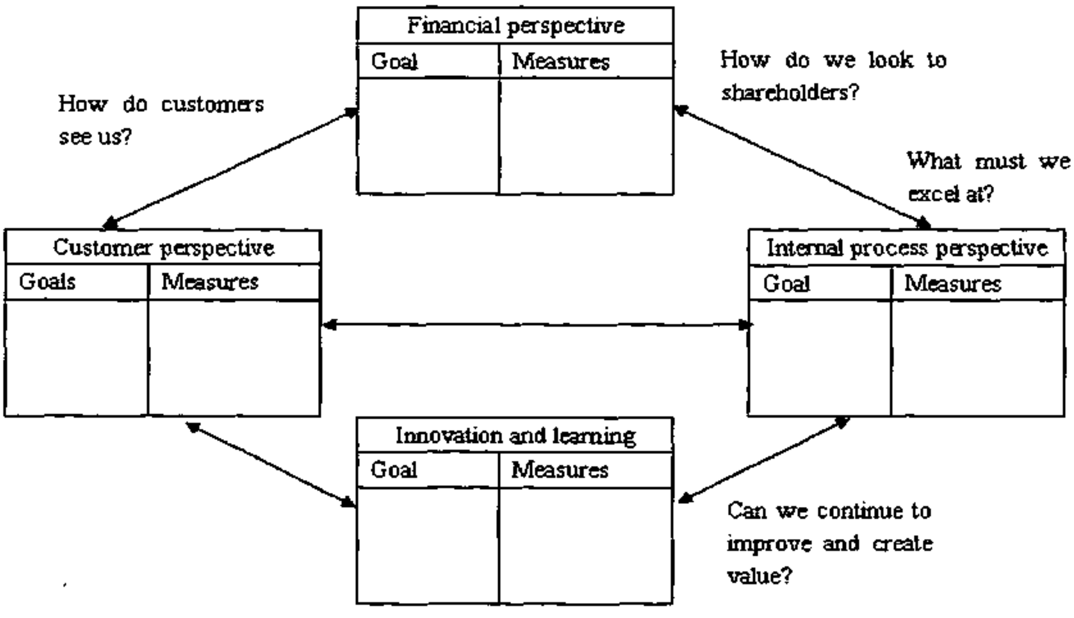
(1) Financial perspective (the investor or shareholder's views);

(2) Customer perspective (the performance attributes valued to customers);

(3) Internal processes perspective (the long-term and short-term means to achieve the financial and customer objectives);

(4) Innovation and learning perspective (capability to improve and create value).

Figure 2-8: The balanced scorecard



Adapted from: Kaplan and Norton (1992)

The balanced scorecard provides answers to four basic questions. The research applies Kaplan and Norton (1992) theory in the automotive industry as:

Financial perspective:

The financial measures address the question of how automotive manufacturers provide financial return to their shareholders or investors. These specific measures including revenue and sales growth, return on equity.

Customer perspective

The customer measures address how automotive manufacturers offer satisfactory service to customers? These specific measures include new vehicle models, on-time delivery, and vehicle cost, manufacturing time and so on.

Internal processes perspective

Internal business process measures address how automotive manufacturers improve internal processes to maximum operational efficiency? These specific measures including product cycle time, manufacturing productivity and so on.

Innovation and learning perspective

Innovation and learning measures address the question of how automotive manufacturers improve and innovate vehicle technology and design to create more value and satisfy customers. These specific measures including vehicle model design and new product development.

The balanced scorecard is a performance measurement based upon an integrated framework incorporating strategic non-financial performance measures with traditional financial metrics. It provides feedback on both the internal business processes and external outcomes. Also, the system evaluates a company's efforts for future improvement. However, the balanced scorecard is primarily designed for senior managers to provide them with an overall view of performance. Thus it is more manageable to apply it to the strategic business rather than the operational level (Ghalayini and Noble 1996).

In addition, the system focuses on four major area of performance. Simply adding new metrics to the financial ones could result in hundreds of measures, thus the system integrates a company's strategy with a purposely limited number of key metrics in order to avoid information overload. The total number of measures should be limited to between 15 and 20 or three to four metrics for each of the four perspectives. Thus the metrics need to be carefully selected and specific for the company (Business Knowledge Center 2008).

2.5.2 Input and output concept

Some performance measurements put emphasis on the horizontal flows of materials and information within the organization. Most notably are Brown (1996) and Lynch and Cross (1991).

Brown's framework, which is shown in Figure 2-9, attempts to measure three main elements of the operations process: input, transformation and output (Brown 1996):

- *Input measures* are mainly concerned with volume and quality of product components, skilled employees and customer requirements.
- *Process measures* are concerned with design of products and services, production and products delivery.
- *Output measures* are concerned with the quality of products and service, and

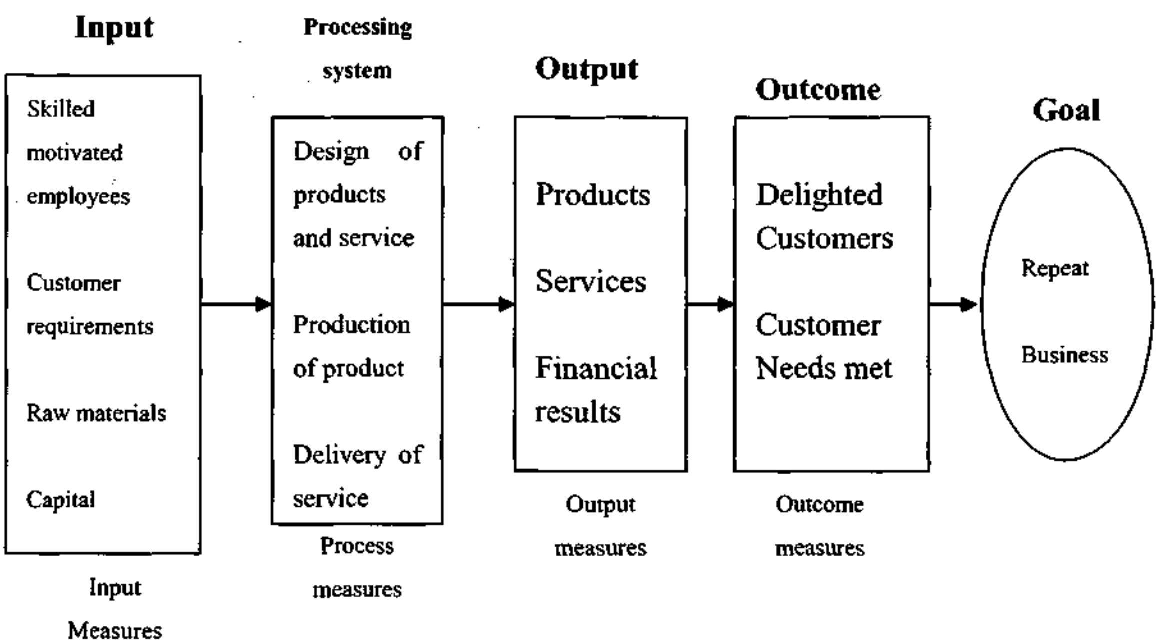
financial results.

- *Outcome measures* are concerned with the satisfaction of the customers.

The selection of the right measures depends on a number of factors. *Brown* (1996) argues that each stage of this framework is the driver of performance. Inputs such as raw materials, capital and skilled employees, can lead to the process system, which can lead output that offers qualify products to customers and provides financial returns to shareholders. At some point, customers are served by the process system which will either achieve or not achieve the outcome intended for them.

Neely and Bourne (2000) clearly identified differences among the input, process and output measures, and the framework promoted a comprehensive approach to measurement of operations and process. However the research agrees with Jonsson and Lesshammar's (1999) comments on the framework which primarily addresses issues within the processing system, such as product design, productivity, cycle time and waste, but fails on evaluation of information flow which is critical for the whole operation. Moreover the framework is difficult to operate during practical implementation because of difficulty to define metrics for each operations process and qualify these metrics.

Figure 2- 9: Inputs, processes, outputs, outcomes



Source: Brown (1996)

2.5.3 Result and determinants concept

Result and determinants concept was proposed by Fitzgerald (1991). Fitzgerald suggested that there are two basic types of performance measures which can be applied to any organization: related to results and determinants of results. Measures that are related to results are: competitiveness and financial performance while measures that focus on the determinants of results are: quality, flexibility, resource utilization and innovation (see table 2-6).

Result and determinants concept has advantages in analyzing the relationship between the determinants and results and provides a balanced framework for operation evaluation. However the research considers that the result and determinants concept has difficulty in defining a set of determinants of the end results that reflects company's objectives and assesses their performance appropriately. Also for measuring process-based supply chain performance in manufacturing companies, the framework is not appropriate due to the emphasis on hard factors and end results.

Table 2-6: Results and determinants framework

Framework	Dimensions of Performance	Measures
Results	**Competitiveness**	Relative market share; Sales growth
	Financial Performance	Profitability; Liquidity; Capital structure
Determinants	**Quality**	Reliability; Courtesy; Availability
	Flexibility	Volume; Delivery speed; Specification
	Resource utilization	Productivity; Efficiency
	Innovation	Performance of the innovation process

Source: Fitzgerald (1991)

2.5.4 Financial and non-financial performance measures

The Institute of Chartered Accountants of Scotland (ICAS) (ICAS 1993) developed a new performance measurement framework, based on the different ways in which businesses use performance measures for: business planning (encompassing a wide variety of non-financial performance measures) and monitoring operations (including mainly traditional financial measures).

The ICAS's framework has strength on integrating all the financial and non-financial performance measures and attempting to integrate all factors to measure the whole performance. Financial related metrics included company's revenue, gross margin, return on investment and sales growth and so on. Non-financial metrics included produce efficiency and flexibility, human resource management, customer retention and growth, product and service innovation and so on. The financial and non-financial performance measures are appropriate to supply chain performance measurement as it enables the incorporation of soft issues, however the research considers the framework is inappropriate as it depends significantly on hard and financial performance measures.

2.5.5 Framework by Beamon

Beamon (1999) asserted the use of resources, the desired output and flexibility are critical to successful supply chain management, therefore, a supply chain measure should emphasize these three separate measures types: resource measures (R), output measures (O) and flexibility measures (F). Beamon (1999) further clarified the different purpose of each measure type (See Table 2-7).

Table 2-7: Goals and purpose of performance measure types

Performance measure	Goal	Purpose
Resources	High level of efficiency	Efficient resource management is critical to profitability
Output	High level of customer service	Without acceptable output, customers will turn to other supply chains
Flexibility	Ability to respond to a changing environment	In an uncertain environment, supply chains must be able to respond to change

Source: Adapted from Beamon (1999)

Beamon (1999) proposed a good view that performance measurement should coincide with the company's strategic goals. This framework allows study of the interactions among the measures and ensures a minimum level of performance on different aspects:

- *Resource measures* are generally measured in terms of the minimum requirements (quantity) or a composite efficiency measure. Measures include inventory levels, personnel requirement, equipment utilization, energy usage, and cost.

- *Output performance measures* must not only correspond to the company's strategic goals, but must also correspond to the customers' goals and values. Output measures include customer responsiveness, quality and the quantity of the final product.

- *Flexibility measures* evaluate a supply chain's ability to accommodate volume and schedule fluctuations from suppliers, manufacturers, and customers, such as volume flexibility, delivery flexibility, new product flexibility.

Beamon's framework has advantages in listing detailed performance measures, and emphasizing process flexibility to respond to environmental change. However the research asserted Neely and Mills's (2000) view that the framework does not address the relationship with suppliers and many output performance measures are difficult to express numerically, such as product quality.

2.5.6 Performance measurement questionnaire

Performance measurement questionnaire (PMQ), presented by Dixon et al, consisted of three stages for measuring performance and encouraging continuous improvement (Dixon, Nanni et al. 1990).

- In the first stage, general data are collected from companies, and respondents assess the companies' competitive priorities and build a performance measurement system. It consists of items labeled as "improvement areas". They are placed in the centre of the questionnaire as shown in Table 2-8.

Table 2-8: Section of part two of PMQ

Long-run important of improvement	Improvement areas	Effect of performance measure on improvement
None >>>> Great		Inhibit >>>> Support
1 2 3 4 5 6 7	Quality	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Labour efficiency	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Machine efficiency	1 2 3 4 5 6 7

Adapted from: Ghalayini and Noble (1996)

- In the second stage, respondents are asked to circle a number on each side of the table in order to identify areas where there is a need to improve and whether the current performance measurements are appropriate to support activity.

- In the third stage, respondents are asked to compare and contrast what is most important for companies and then the respondents are asked to provide appropriate performance measures that best evaluate their own performance and any other general comments.

The performance measurement questionnaire (PMQ) identifies the improvement areas of the company and their associated performance measures. In addition PMQ attempts to determine the extent to which the existing measurement system supports such as improvement areas. However the research advocates Ghalayini and Noble's (1996) view that the performance measurement questionnaire (PMQ) failed to link areas of improvement and performance measures in the manufacturing process. Also the performance measurement questionnaire (PMQ) does not take into account the concept of continuous improvement.

2.5.7 Performance of activity (POA)

A supply chain should be viewed as one single entity and managed as a whole, Chan and Qi (2003) proposed an innovative approach to assess supply chain performance: the concept of performance of activity (POA).

The selection of the dimensions is based on actual requirements: internal people and external customers, the metrics can be divided into: hard measures and soft measures. The hard measures include cost, time, capacity, productivity, and utilization; the soft measures include: effectiveness, reliability, availability and flexibility.

The concept of POA integrates supply chain performance measurement. Performance metrics cover a broad range, including inputs and outcomes, both tangible items and intangible items. It not only provides an approach to identify and select the performance measures, but also develops benchmark performance among the processes and activities.

The research recommends that the POA concept is appropriate to process-based manufacturing. However, it does not address the external environment, such as competitors and support continuous improvement for the future development.

2.5.8 Frame work by Gunasekarn

Gunasekaran et al. (2001) proposed a new supply chain performance framework. The metrics discussed in this framework are classified into strategic, tactical and operational levels of management. Rushton (2001) directly distinguished the influence of different levels of management:

- The strategic level measurements affect the top level management decisions, very often reflecting investigation of broad based policies, company's financial plans, competitiveness and organizational goals.

- The tactical level measurement of performance offers valuable feedback to mid-level management decisions. It deals with resource allocation to achieve results specified at the strategic level.

- Operational level measurements and metrics require accurate data and assess the impacts of decisions upon low level managers. Supervisors and workers are operational objectives to the achievement of tactical objectives.

According to Gunasekaran et al's view, these metrics have been to be assigned to where they can be best dealt with by the appropriate management level and for fair decision making. An example is given, the total cycle time, assigned at the strategic level based on an overall system decision in a supply chain and can be used and managed by the top managers. In Table 2-9, Gunasekaran et. al (2001) show the metrics for the evaluation of supply chain performance:

Table 2-9: A framework on metrics for the performance evaluation

Strategic Level	Tactical Level	Operational Level
Total supply chain cycle time Total cash flow time Customer query time Level of customer perceived value of product Net profit vs. productivity ratio Rate of return on investment Range of product and services Variations against budget Order lead time Flexibility of service systems to meet particular customer needs Buyer-supplier partnership level Supplier lead time Level of supplier's defect free deliveries Delivery lead time Delivery performance	Accuracy of forecasting techniques Product development cycle time Order entry methods Effectiveness of delivery invoice methods Purchase order cycle time Planned process cycle time Effectiveness of master production schedule Supplier assistance in solving technical problems Supplier ability to respond to quality problems Supplier cost saving initiatives Supplier's booking in procedures Delivery reliability Responsiveness to urgent deliveries Effectiveness of distribution planning schedule	Cost per operation hour Information carrying cost Capacity utilization Total inventory as: Incoming stock level Work-in-progress Scrap level Finished goods in transit Supplier rejection rate Quality of delivery documentation Efficiency of purchase order cycle time Frequency of delivery Driver reliability for performance Quality of delivered goods Achievement of defect free deliveries

Adapted from Gunasekaran (2001)

Gunasekaran's framework has been developed from the literature and provides metrics for the strategic, operational and tactical level based on the supply chain process. The research considers Gunasekaran's framework is very useful in performance evaluation as it incorporates issues such as suppliers' performance and customer satisfaction. But the framework does not identify improvement, and it is too complex to adopt for the model to be used in this evaluation.

2.5.9 Summary

The previous section has sought to illustrate various performance measurement frameworks, the research finally summaries each measure framework's key features, strength and weakness in table 2-10:

Table 2-10: Performance models and their weaknesses

Framework	Key Features	Strength	Weakness
Balanced scorecard by Kaplan and Norton (1992)	Identifies financial, customer, internal business, and innovation and learning perspectives. Integrating financial and non-financial, internal and external measures.	Very useful tool for management. It integrates non-financial measures, soft issues, and encourages continuous improvement.	More focuses on strategic business rather than operational level. Also limited metrics for evaluation.
Input and output concept by Brown (1996)	Provides a comprehensive approach to manage and measure operations. Also identifies differences among the input, process and output measures.	Introduce a process-based approach to measure three main elements: input, transformation, output by using quantitative approach.	Fails on evaluation of information flow which is critical for the whole operation.And difficult to apply during implementation.
Results and determinants concept by Fitzgerald et al.(1991)	Two types of performance measures are proposed: related to results and determinants of results.	Attempts to identify the relationship between the result measures and the determinants measures.	Difficult to find the determinants and not appropriate to manufacturing company due to emphasis on hard factors and end result.
ICAS (2000)	Both financial and non-financial performance measures based on planning and monitoring operations	It attempts to integrate all factors to measure the whole performance.	The framework fails for significant depending on hard and financial performance measures.
Framework by Beamon (1999)	Uses resources, output and flexibility as components. It provides a quantitative approach for flexibility measurement.	It provides a detailed performance measure list, and emphasizes flexibility to respond to environmental change.	The framework does not address the relationship with suppliers and many output performance measures are difficult to express numerically, such as product quality.

Performance measurement questionnaire by Dixon et al. (1990)	Present three stages for measurement questionnaire and place emphasis on identifying performance improvement areas.	Questionnaire structure for identifying performance measures and encouraging improvement.	Not to link areas of improvement and performance measures on the manufacturing process. Also PMQ failed to take into account the concept of continuous improvement.
Performance of activity by Chan and Qi (2003)	The concept of POA covers a broad range of performance metrics, including inputs and outcomes, both tangible items and intangible items.	It not only provides an approach to identify and select the performance measures, but also develops benchmark for operations.	It is appropriate to integrate supply chain performance measurement, however, it does not address external environment and support continuous improvement
Framework by Gunasekarn et al. (2001)	It provides metrics for strategic, operational and tactical level based on basic process.	It could be very useful in performance evaluation due to incorporating issues such as suppliers performance and customer satisfaction.	The measures is developed from the literature, however the framework does not identify improvement area, and too complex to adopt this model.

Source: the author

2.6 Overview of different mathematical evaluation methods

The previous section introduced a wide range of performance methods and their framework. In this section, the research will review five different mathematical evaluation methods that can integrate with performance framework for the evaluation. These mathematical methods include: fuzzy comprehensive evaluation method, grey comprehensive evaluation, data envelopment analysis (DEA), artificial neural network

(ANN) and analytic hierarchy process (AHP). The research will select the most suitable method-The Analytic Hierarchy Process to evaluate supply chain management in the automotive industry.

2.6.1 Fuzzy comprehensive evaluation method

Fuzzy mathematics was developed by professor L.A. Zadeh who is an automatic control expert from the United States (Zadeh 1978). Fuzzy comprehensive evaluation is a branch of fuzzy mathematics which is further developed by Chinese researcher PeiZhuang Wang (Wang and Han 1989). Fuzzy comprehensive evaluation method is a mathematical method to comprehensively evaluate things that are not easy to be clearly defined in the real world (Shao 2009). In many real-world applications, the data for evaluation are often collected from investigation by using natural language such as poor, fair, good, very good and excellent which are used to reflect a kind of general situation of the investigated entities rather than a specific case, thus it has the potential to be regarded as an efficient measurement for the subjective performance measurement (Nagano, Yamaguchi et al. 1995; Guo and Tanaka 1998).

Fuzzy comprehensive evaluation is a simple and flexible method used in practice, however the primary issue associated with this method is natural language may not determinate appropriate weight to be used in calculating metrics for performance evaluation (Wang and Xie 1996).

2.6.2 Grey comprehensive evaluation

Grey Systems theory is a new method developed by Chinese professor Julong Deng in 1982 (Deng 1985). Grey systems emphasize studying general uncertainty and various possibilities of investigating information from different sources (Jun 1990). Grey systems theory uses a black-grey-white color spectrum to draw out valuable information from the generating and developing of the partially known or known information. The grey comprehensive evaluation firstly sets the objective of performance measurement and chooses metrics and then is used to investigate the relation of each metric between participants and in a sample case which has the best performance, the higher the relationship ratio the better.

2.6.3 Data Envelopment Analysis (DEA)

There are two non-parametric approaches for evaluating efficiency: Data Envelopment Analysis (DEA) and Artificial Neural Network (ANN). DEA is a linear programming based methodology for evaluating performance by comparing different Decision Making Units (DMUs) productivity based on multiple inputs and outputs (Charnes, Cooper et al. 1978; Johnes 2006). The efficiency on performance measure of a Decision Making Unit (DMU) is defined by its position relative to the frontier of best performance established mathematically by the ratio of weighted sum of outputs to weighted sum of input (Norman and Stoker 1991). The ratio of weighted outputs and inputs produces a single measure of productivity called relative efficiency. If DMUs have a ratio of 1 that is referred to as efficient given the required inputs and produced outputs. If the units have a ratio less than 1 that refers less efficient relative to the most efficient units (Seiford 1996).

2.6.4 Artificial Neural Network (ANN)

An Artificial Neural Network (ANN) is "a mathematical model that is inspired by the functional aspects of biological neural networks. In most cases, an ANN changes its structure based on external or internal information that flows through the network during the learning phase. Learning in biological systems includes adjustments to the synaptic connections that exist between the neurons. Modern neural networks usually used to model complex relationships between inputs and outputs or to find patterns in data" (Wikipedia Website 2010). In recent years, an ANN has been used as a powerful non-parametric approach for modeling the nonlinear relations in a number of efficiency evaluations. The radial basis function neural networks (RBFNN) have proved significantly beneficial in the evaluation and assessment of complex systems (Aslani, Momeni-Masuleh et al. 2009).

2.6.5 Analytic Hierarchy Process (AHP)

AHP, is a popular decision structuring and analysis tool, originally proposed by Thomas L. Saaty in the early 1970's. AHP is a mathematical theory of value, reason, and judgment, based on ratio scales for the analysis of multiple-criteria decision-making problems (Saaty 2001). In reality, AHP is a comprehensive framework which is designed to model real world decision problems when we make multi-objective, multi-criterion and multi-actor decisions for any number of alternatives (Erdoğmuşa, Arasb et al. 2006).

An AHP model typically consists of a set of complex issues which have an impact on the solution to the problem. It breaks down the decision problem to a hierarchical structure and derives priorities for the elements in each level of hierarchy according to their impact on the elements (e.g., criteria or objectives) of the next higher level (Saaty 1983). Pairwise comparisons are made on a scale of relative importance where the decision maker has the option to express the preferences between two elements on a ratio scale from equally important (i.e., equivalent to a numeric value of one) to absolute preference (i.e., equivalent to a numeric value of nine) of one element over another (Saaty 2001).

AHP has been widely used in different decision-making processes by academics and practitioners. Erdoğmuşa et. al (2006) summarized the application of the Analytic

Hierarchy Process covering: policy development in the energy market (Chedid 2002; Chedid.R.B 2002); macroeconomic forecasting (Blair, Nachtmann.R et al. 2001); university resource allocation (Kwak and Lee 1998); information system project selection (Schniederjans and Wilson 1991); and information resource planning for health–care systems (Lee and Kwak 1999); evaluation of natural resources (Jaber and Mohsen 2001); working preferences for banks (Ta and Har 2000); software selection (Lai, Wong et al. 2002); supplier evaluation (Mohanty and Deshmukh 1993); selection of electric power plants (Akash, Mamlook et al. 1999); choosing alternative fuels for land transportation (Poh and Ang 1999); decision of agricultural technologies application (Alphonce 1997); determination of a distributed system reliability (Fahmy 2001); and selecting the location for a restaurant (Tzeng, Teng et al. 2002), distribution centre (Kengpol 2002), convenience store (Kuo, Chi et al. 2002), facility location (Yang and Lee 1997) and so on.

AHP also has been extensively applied and sometimes combined with other mathematical programming methods in developing business and manufacturing operation performance evaluation (Lee, Kwak et al. 1995; Rangone 1996). Rangone (1996) considered AHP is used to measure the performance on the basis of multi-attribute criteria. AHP can help evaluators to assess the overall contribution to achieving the objective, by linking the priorities of performance measure at every level of the hierarchy structure (Rangone 1996). Application areas are as follows:

manufacturing performance (Rangone 1996); operational performance of intensive care units (Dey, Hariharan et al. 2006); performance of third-party reverse logistics providers (Meade and Sarkis 2002); information sharing capabilities (Shore and Venkatachalam 2003); and logistics performance of the postal industry (Ramadhan, Wahhab et al. 1999 ; Chan, Lau et al. 2006); process performance (Frei and Harker 1999) and other advanced manufacturing systems justification and selection (Wabalickis 1987).

2.6.6 Discussion of mathematical methods

In the previous section, the research presented five different mathematical methods that can be used in performance measurement.

Fuzzy comprehensively evaluation and grey comprehensive evaluation have common characters: they are simple and easily computerized using a database and available data or information can base on vagueness and uncertainty, and option. The calculation of fuzzy comprehensive is similar to the AHP, they need to determine the importance of each evaluation metrics by expert judgments and determine the relative weight of metrics by multiplying the vector of the metric weight and the each metric (Zhang, Lin et al. 2002). Fuzzy comprehensive evaluation methods mostly reflect the nature of subjective assessment without limitation of scale. However the metric weight is usually given by the experts based on experience can not help with subjectivity (Zhu 2005). Contrarily AHP is better at comparing metrics and computing metrics weight based on 1-9 points. Also compared to AHP, grey comprehensive evaluation is difficult to decide the best performance sample and to set up the optimal sample data. Otherwise the method is good on presenting the evaluation results rather than to clearly present data for analysis.

Both DEA and ANN are more difficult on calculation compared the previous two methods. DEA is able to measure multiple inputs and outputs, however DEA appears efficient simply because of its pattern of inputs and outputs and not because of any inherent efficiency (Wong and Wong 2007). Moreover the inputs and outputs measures that contribute to the objective of performance measurement used in DEA do not require assigned numeric weights and modeling preferences for analysis, thus DEA may not provide the useful information to the evaluator about metrics priority or value (Wong and Wong 2007; Banwet and Deshmukh 2008). Thus integrating experts' judgment can provide more information in terms of metrics comparison, metrics selection, value, and performance weakness improvement.

After consideration of the above factors, eventually AHP was selected as a precise and effective performance evaluation method used in this research. AHP has several advantages used in this research: firstly AHP is easily understood and the calculation can be computerized by using several softwares, such as expert choice and AHP software. Secondly AHP is a flexible tool and can be applied to any hierarchy of performance measures, whatever the number of levels, of measuring metrics and of the scope of performance measures. Thirdly AHP enables people to refine their definition and perception of problems and criteria and considers relative priorities based on an objective measure and criteria. AHP provides a structure for the problems and facilitates managers to better understand the problems and better control the overall operational and procedure performance measures. Finally AHP decomposes a complex problem into criteria and elements, AHP tracks the logical consistency of judgments and provides a scale and method for measuring intangibles for establishing priorities (Satty 1995).

Conclusion

The research has explored six parts in chapter 2. Firstly the research introduced supply chain management. Following automotive supply chain management has been mentioned as well. In third part, the research clarified the Chinese automotive industry and its characteristics. Performance measurement definition and history, procedure and application have been demonstrated in the fourth part. Then in the next part, the research demonstrated and compared five different mathematical evaluation methods. Finally the research chose AHP as a suitable method used in evaluation of practical supply chain operations in the Chinese automotive industry.

Chapter 3 Discussion of methodology theory

An overview of the research was provided and an outline of the research structure and objectives in chapter one. Chapter 2 outlined a literature review of performance measurement and the Chinese automotive industry. In the context of this discussion so far and the selection of AHP as the chosen methodology, the purpose of this chapter is to:

- Discuss the research philosophy, including positivism, interpretivism and realism.
- Expound the research approach including deductive and inductive.
- Present the research strategy that has been developed and utilized in the research
- Consider the research time horizon
- Present data collection methods, including tactics used to obtain a high level of reliability and validity.

3.1 Research philosophy

The relationship between research philosophy and research method is important. The research should assess clearly what research philosophy will be adopted before conducting the research project. Easterby-Smith et al (2002) highlighted the factors behind research philosophy which allow the researcher to:

- Take a more informed decision about the research approach;
- Decide which methods are appropriate for the research;
- And to think about constraints which may impinge on the research

There is no common agreement regarding the types of key research philosophies. Saunders et al (2009) suggest there are three most common research philosophies: positivism, realism and interpretivism, while Riege (2003) point out there are four main research philosophies: positivism, realism, critical theory and constructivism. Stiles (2003) points out the main research philosophies as positivism, symbolic interactions, ethnomethodology, realism, idealism and phenomenology. Taking these views, the research focuses on three main philosophies that dominate the literature: positivism, interpretivism, and realism.

3.1.1 Positivism

Positivists believe that reality is stable and can be observed and described from using an objective method, rather than being inferred subjectively through sensation, reflection or intuition (Levin 1988; Smith, Thorpe et al. 1991). They contend that phenomena should be isolated and that observations should be repeatable (Smith, Thorpe et al.

1991). Positivist research is theory driven, and has a defined research plan which is designed to prove that a predefined hypothesis is true (Clark 2004). Quantifiable observation allows researchers to familiarize themselves with the problem or concept to be studied. The emphasis is on facts and causes of behavior, with the information in the form of numbers that can be quantified, and summarized using a mathematical process for analyzing the numeric data and expressing the final result in statistical terminology (Bogdan and Biklen 1998).

3.1.2 Interpretivism

The interpretivist research philosophy assumes that the world is just as people perceive it to be (Cavana, Delahaye et al. 2001), therefore the aim of interpretivist research is for researchers to "uncover the socially constructed meaning as it is understood by an individual or a group of individuals" (Cavana, Delahaye et al. 2001) and to "describe it in a way that is meaningful for these research participants" (Saunders 2003). Saunders (2003) claimed the role of the interpretivist is to seek to understand the subjective reality of those that they study in order to be able to make sense of their motives, actions and intention (Saunders 2003). In other words, social constructionism suggests that reality is subjective and it is socially constructed and given meaning by people.

3.1.3 Realism

Stiles (2003) suggests "if positivism is considered to locate at one end of the spectrum of paradigms and interpretivism towards the other end, then realism bridges these perceived extremes, overlapping each". Realism accepts people's understanding of the world emanated from their personal perspective and therefore knowledge of a situation needs to be examined "insight out" (Stiles 2003). However this understanding is qualified by the realist researcher's appreciation that this form of knowledge might be "partial or incomplete" and therefore needs to be complemented by the use of a theoretical framework that "determine the underlying mechanisms that influence people's action" (Stiles 2003). The realistic philosophy shares two features with a positivism philosophy: a belief that the natural and the social sciences should apply the same kinds of approach to the collection of data and to explanation, and a commitment to the view that there is an external reality to which scientist direct their attention (Bryman 2001).

Based on the differences of the three philosophies, the study can be classified best as more interpretivistic. This is because the objective of this research is to evaluate supply chain performance in the automotive industry and propose some improvement suggestions in terms of weaknesses of supply chain management that exist. This research is of an exploratory nature which is a kind of social constructionism. Cooper and Schindler (1998) stated that "exploratory studies tend toward loose structure with objective of discovering future research tasks" and "exploratory research is usually small-scale research undertaken to define the exact nature of the problem and gain a better understanding of the environment within which the problem occurred" (McDaniel and Gates 1999).

Otherwise an interpretivistic approach is appropriate, because no theories have been found to describe the study phenomenon. We do not know the characteristics of supply chain management performance in the Chinese automotive industry. The research needs to seek to explain a phenomenon based on practical investigation.

In conclusion, the objectives and conditions of the research fit well with adopting the interpretivism philosophy of the exploratory nature of this study.

3.2 Research approach

Saunders et al. (2009) claimed that there are two most commonly research approaches deductive and inductive. These two research approaches both comprise the steps of data collection and theory development, but they are in opposition to each other.

Saunders et al (2009) defined a deductive approach as developing a theory or hypothesis based on existing facts and theories in a particular area, for which the researchers design a research strategy and test a theoretical proposition. Opposed to the deductive approach is the inductive approach, Saunders et al (2009) defined an inductive approach as researchers collecting data and developing a theory as result of data analysis. Dick (2002) suggested that the deductive can be considered going from theory to practice, while the inductive approach is going from practice to theory.

Saunders et al (2009) further clarified the major difference between the two research approaches as shown in table 3-1:

Table 3- 1: Deductive and inductive research

Deduction	Induction
• Scientific principles • Moving from theory to data • Need to explain causal relationships between variables • Collection of quantitative data • Application of controls to ensure validity of data • Operationalisation of concepts to ensure clarity of definition • Highly structured approach • Researcher independence of what is being researched • Necessity to select samples of sufficient size in order to generalize conclusions	• Gaining an understanding of the meanings humans attach to events • Close understanding of the research context • Collection of qualitative data • More flexible structure to permit changes of research emphasis as the research progresses • Realization that the researcher is part of the research process • Less concern with the need to generalize

Source: Saunders et al (2003)

An inductive research approach is considered the most appropriate for an interpretivistic research philosophy (Saunders 2003). Otherwise an inductive approach is applicable to business and management studies where established theories are unlikely to be available (Remenyi 2004). This research develops analysis and suggestions for the automotive supply chain management from practical investigation based on sample automotive companies. Thus the research follows the inductive approach.

3.3 Research strategy

Hussey and Hussey (1997) identified that "there are four types of research purpose existing: exploratory, descriptive, analytical or predictive". Whatever the purpose of the research, empirical evidence is important and necessary. They defined empirical evidence as "data based on observation or experience". The research design has an empirical research approach to explore automotive supply chain performance in China.

A large number of research strategies have been identified which included (Galliers and Land 1987; Miles and Huberman 1994; Hussey and Hussey 1997; Paul. D and E.Ormrod 2001; Leedy and Ormrod 2004): laboratory experiments and field experiments (commonly used in pure scientific research); surveys (often used where massive data are involved with quantitative analytical techniques); case studies (which seek to understand social phenomena within a particular setting); simulation (involve copying the behavior of a system); Forecasting/futures research (involves the use of techniques such as regression analysis to make predictions) and modeling (where particular models are developed as the focus of the research activity); operational research (which looks at activities and seeks to understand their relationship, often with particular emphasis on operational efficiency). For the purpose of this research, research strategies considered here are: survey, case study and phenomenological study.

3.3.1 Survey

Galliers (1991) explained that surveys enable the researcher to obtain data about practices, situations or views at one point in time through questionnaires or interviews. Thus surveys are a common approach in business and management research, offering an opportunity to collect large quantities of data or evidence (Saunders et al. 2003). Saunders et al (2003) further emphased that a survey is "the collection of a large amount of data from a sizeable population in a highly economic way". In contrast, interviews rely on closer direct contact between the researcher and interviewees, also the number of interviewees are smaller than survey participants. According to the research objectives, the research needs to investigate academics and practitioners' opinions and suggestions on empirical collection. Thus a survey is administered to get experts feedback before the practical data collection and interviews are also used as part of the empirical data collection.

3.3.2 Case study

There are a number of researchers who describe the case study approach, Saunders et al (2003) captured common elements of these definitions and defines case study research as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence"

Benbasat et al. (1987) defined a case study as examining "a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups or organizations)". Multiple cases are more valid and generalisable compared to a single case (Lee 1989). Yin (1999) identified multiple methods as following:

- Direct observation of activities, phenomena and environment;
- Indirect observation or measurement of process related phenomena;
- Interviews - structured or unstructured;
- Documentation, such as journal, conference paper or news about the company and

its operations;

- Records and charts about previous use of technology relevant to the case.

This research used case studies as the research strategy to empirically investigate a "particular phenomenon" (Saunders 2003), the research following Hussey and Hussey's (1997) recommended procedure:

- Firstly, the research selects a number of possible automotive companies after a preliminary investigation.

- Secondly, the research gathers empirical data including both qualitative and quantitative data through a series of semi-structured interviews. In addition documents and observations are assembled as well as the gathering a number of artefacts (documents and so on) to assist in extending data collection depth.

- Finally the research analyzes the collected data and submits in the form of a report for academic purposes.

3.3.3 Phenomenological study

Leedy and Ormrod (2001) clearly described the purpose of phenomenological study as "to understand an experience from the responders' point of view". The phenomenological study focuses on the respondent' perceptions of the event or situation and the study tries to analyze the question of the experiences.

The method of collecting data is through 1-2 hours interviews in order to understand and interpret a responder's perception on the meaning of an event. The research conducts semi-structured interviews to collect data on each metric's scale based on 1-9 point and explore academics and practitioners' perceptions of automotive supply chain operations. The research follows Creswell's suggestions in terms of procedural format (Creswell 1998): Firstly the researcher writes the research questions to explore the experts' view on supply chain operations, including supply chain operational weakness and recommendation for improvement. Secondly the researcher conducts the interviews, then analyzes and reports experts' perceptions on Chinese automotive supply chain management.

3.4 Time Horizon

For all types of research, the time limit is very crucial for most researchers. Saunders et al (2009) identified two types of studies: cross-sectional studies and longitudinal studies. Saunders et al (2009) defined cross-sectional studies as "the study of a particular phenomenon at a particular time", while longitudinal studies investigate phenomena several times if there have been any changes or developments over a period of time. The cross-sectional research is in the form of a "one-shot" which means data are gathered just once to answer a research question. Longitudinal research is in the form of "multiple-shots" which means a study can be done several times over a period of time in order to answer a research question.

The research collects multiple sources from Chinese automotive companies over a restricted period of several months. The research design is "the study of a particular phenomenon at a particular time", and data has to be collected at one point in time. Thus the research is a cross-sectional design.

3.5 Data collection methods

A wide variety of possible data collection methods are available. The research uses multi-method approaches to collect data. Each of these major data collection methods used during this research study will be explored in more detail.

3.5.1 Sampling

Many authors agree that two types of data sampling exists (Welman and Kruger 1999; Gerson and Horowitz 2002), Castillo (2009) distinguished these two data sampling techniques as:

Probability sampling is a product of a randomized selection processes which includes simple random sampling; systematic sampling; stratified random sampling, and cluster sampling.

Non-probability sampling is usually selected on the basis of their accessibility or by the purposive personal judgment of the researcher. Non-probability sampling is a sampling technique where the samples are gathered in a process that does not give all the individuals in the population equal chances of being selected.

Miles and Huberman (1994) classified non-probability sampling as: the accidental sample, the quota sample, the purposive sample, the self-selected sample and the incomplete sample. Leedy and Ormrod (2001) stated that purposive sampling is used where people or other units are chosen for a particular purpose, implying the use of judgment on the part of the researcher. In this research, there are more than a hundred automotive companies in China. Hence a particular sampling approach was used for evaluation and analysis. The research only chose the top ten companies, as not only do these companies take a big market share, but also bigger companies were more accessible to get the data required. The sampled automotive companies "tend to be purposive rather than random". Also the research applied the purposive sampling method on a small pre-survey to ensure the procedure of empirical data collection reliability. The research drew experts from academic published journals, conference attendance lists or employee lists. These experts either have efficient knowledge of the supply chain and AHP research or have massive experience in supply chain operations. Considering the nature of the research, the purposive sampling method is selected as the most appropriate.

3.5.2 Survey and Interview

Data was collected from a variety of sources, including documents and people. Two means of collecting data from people were used: surveys and interviews. The research used both a small pre-survey and expert interview. A small pre-survey was conducted at the first stage for two reasons: firstly, to avoid inapplicable questions, ambiguous wording, and its appropriateness for interviewing and collecting data. Secondly, the initial performance metrics and formulas are reviewed by several academics and practitioners, and their feedback and advice are used to modify an interview assessment form. Forms of research questions included "if performance metric selection is correct" "if the metrics' formula is correct" and "where to collect these data". At the second stage, the expert interview is used.

Welman and Kruger (1999) described three types of interviews as:

- Structured interview: offers a series of fixed responses, using closed questions.
- Semi-structured interview: offers free responses from participants to specific questions.
- Unstructured interview: allows the participants to express themselves without any restriction.

A semi-structured interview is used when the researcher wants to fully understand the perception or experiences of interviewees or wants to learn more about their answers to the questionnaires (Creswell 1994). Semi-structured interviews allow researchers to understand more fully respondents' opinions compared with a mailed questionnaire. An interview is a good data collection technique to get in-depth information and it is particularly useful for getting the story behind a participant's experiences (Borg, Gall et al. 1989). An interview is the process of the communication between the interviewer and interviewee.

A semi-structured interview is appropriate to this research because of its ability to combine depth and objectivity. It allows experts to express of their opinions in terms of supply chain operations in Chinese automotive companies. However interviews are a method that takes much time and may lead to bias. So it is important to design appropriate questions and the process of the interview. The research follows Rubin and Rubin's recommendations for designing interviews (Rubin and Rubin 1995):

At the first stage, the researcher separately asks interviewees to assign importance to the metrics, sub-metrics and sub-sub metrics in the hierarchical model by pairwise comparison. The researcher introduces the research topic and interview's objectives.

And Satty's 1-9 points[6] scale of 10 measurement items that contribute to the performance of supply chain management are applied during the interview. The researcher records experts' score and reasons for their judgment. Also the researcher checks consistency of experts' score by using Yaahp software. If an expert's scale is inconsistent, the researcher will encourage an expert to revise their earlier judgment.

At the second stage, in order to obtain more knowledge regarding supply chain management in the Chinese automotive companies, the researcher guides the discussion by asking specific questions. These questions are essentially focused on issues related to the implementation of supply chain management in the Chinese automotive industry, especially developed towards identifying any weakness of management and how to improve it. The designed questions for the interview are summarized as follows:

- Do you think supply chain management is important to automotive companies?
- What do you think of the current supply chain operations in the automotive industry in China? Do you think the current supply chain management in automotive companies is inefficient?

[6] The measurement items are measured on a nine-point scale, ranging from an anchor 1-uqual importance, 3-moderate importance, 5-essential or strong importance,7-very strong and demonstrated importance, 9-extreme importance.

- What is the gap between practices of supply chain operations in China and those in developed countries, such as American, Japan and Germany?
- What are the main problems with supply chain management at the moment?
- What are the challenges faced by automotive companies in the immediate future?
- What inhibits the development of supply chain management in the Chinese automotive industry?
- What are your suggestions for automotive companies to improve their management?

During interviewing, all the questions are addressed and clarified. In keeping with the semi-structured interview, conversations are allowed to proceed at their own pace (Sutton and Callahan 1986). The same questions are asked to each of the different interviewees, although the researcher is allowed to modify the order of the questions based on the context of the conversation, change the wording of questions and to lead to particular or additional questions that experts are familiar with (Robson 2002). Each interview time is approximately an hour, although the time varies from 30 minutes to two hours depending on the work schedule on the day of visit. Repeat visits are sometimes needed to pick up additional contacts.

3.5.3 Primary and secondary data

A considerable quantity of empirical data was gathered during this research. Primary data and secondary data are both used. Ghauri and Gronhaug (2002) defined primary data as original data collected by researchers for the research questions and secondary data are information collected by other researchers for other different purposes. Saunders et al. (2003) clarified primary data collection techniques including interviews, questionnaires, focus groups and case studies and so on. Compared to secondary data which may be only superficial, primary data can be more in-depth and informative. Among secondary data collection techniques, documentation review is a quick and accurate means to collect existing information and historical information. The method used here is to collect data through reviewing the formal company documents and reports about production, sales and finance (Saunders et al 2003).

Both primary and secondary sources are major sources of data used in this research. Primary data was directly collected from the sample automotive companies, whilst secondary data are collected and used in quantitative analysis of performance metrics. Archival documentation includes feasibility studies, public and internal financial reports, companies' memos and proposals, newspaper articles, and related journals and books are reviewed and analyzed.

3.5.4 Observation

Gillham (2000) and Powell (1997) considered observation as a valuable data collection method to complement interviews. Gillham (2000) defined observation as watching what people do, listening to what they say, and sometimes asking them to clarify questions. Neuman (2000) pointed out that the researcher becomes an instrument that absorbs all source of information.

Observation allows the researcher to identify possible additional artefacts and documents as part of the data collection activities. This research used a tour to observe some retailers and manufacturers in order to add depth and variety to the data collected. There are two purposes to these tours: firstly, to complement and verify the information collected from interviews and documentation. Secondly, to collect Chinese automotive companies' empirical data for some sub-sub-metrics, such as vehicle delivery time and customer dissatisfaction areas.

3.5.5 Data reliability and validity

Denscombe (1998) described reliability as obtaining the same finding even when another researcher does the research. McMillan and Schumacher (1993) stated that reliability is addressed through study designs and data collection strategy to maximize the consistency of the researcher's interactive style, data recording, data analysis, and interpretation of participant responses from the data. Many authors (Gillham 2000; Easterby-Smith, Thorpe et al. 2002) considered that triangulation is an efficient approach to increase the quality and validity of the qualitative research methods. Darke et al. (1998) advocated the use of triangulation to avoid bias on the part of the researcher, either in terms of the researcher influencing participants' behavior or in terms of bias the researcher introduces herself into the conduct of the research. Gillham (2000) also advocated triangulation as a method of validating the research. The triangulation used here following Stakes' recommendation in this research (Stake 1995):

- Data source triangulation: use variety of data within the same research (Denzin and Lincoln 2000).
- Investigator triangulation: use several different researchers to collect data, review and analyze the findings.
- Theoretical triangulation: the use of multiple theoretical perspectives in research to collect data and analysis.
- Methodological triangulation: use a variety of data gathering tools and techniques

In this research, multiple sources are used, and these include empirical data which was directly collected from automotive companies, and indirect data collected from public sources or internal sources such as automotive conferences and automotive supply chain associations. Also other data sources such as researcher' observation and interviewees' views are used. During research evaluation and analysis, the research also considers these factors:

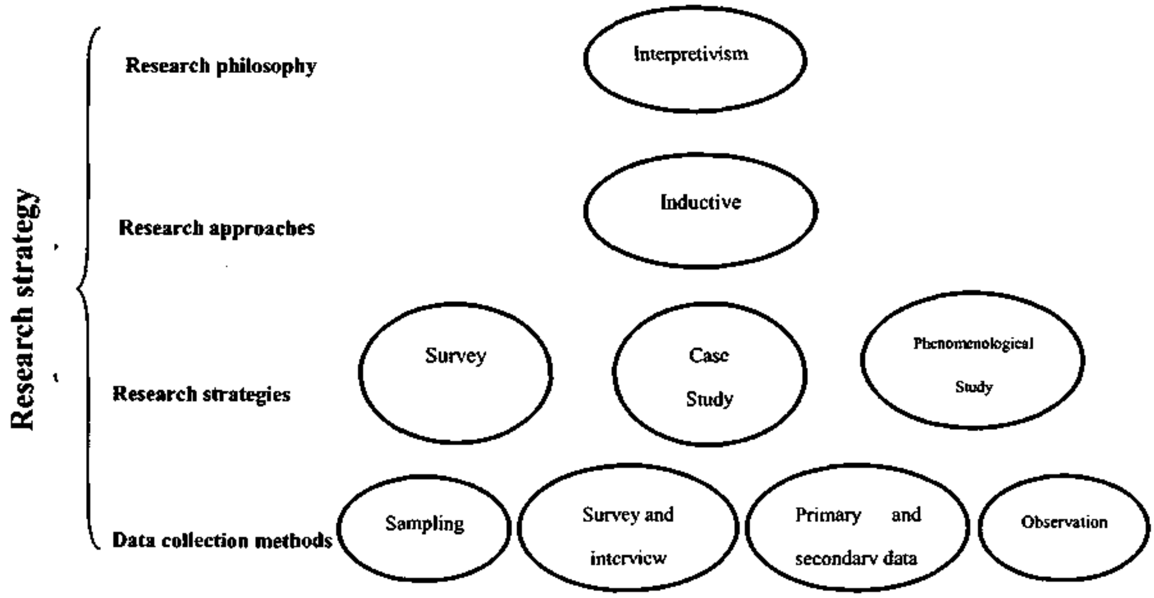
1) Comparing data collected from different sources, choosing the latest or authoritative data and complementing observation data with interview perception.
2) Considering the perspectives of people from different points of view, such as employees' view, customers' views, and managers' views and so on.
3) Considering good points from other researcher's research and expert's view.

Also in order to check reliability and validity of metric selection, the research establishes pre-survey procedures at the initial data-gathering phase to ask experts' opinions on an empirical data collection form. During the semi-structured interviews, the researcher contacts experts from both supply chain research and supply chain operational areas. The research takes two rounds to collect experts' view and finally uses an average score to reduce experts' diversity. Moreover, considering some empirical data are not available, the research expresses empirical data in percentage or ratio, and uses Huo and Ma's theory (2002) to quantify empirical data to reduce the data difference.

3.6 Summary

In this Chapter the overall research design, and the underlying research philosophy, the research approach and the research strategy are discussed, as summarized in Figure 3-1. The research has characteristics of an interpretivistic research philosophy, and can probably best be classified following an inductive research approach. The appropriate research strategies used for supply chain performance evaluation in the Chinese automotive industry are survey, case study and phenomenological study. The research is a cross-sectional design. Data collection methods include sampling methods, surveys and interviews, primary data and secondary data, and observation. Possible criticism regarding the research reliability and validity are discussed as well. The research attempts to enhance the research reliability and validity by taking appropriate triangulation methods in terms of data source, investigator, and methodologies.

Figure 3- 1: Research philosophy, approach and strategy



Source: the author

Chapter 4 Methodology of evaluation

In this section, the research will present the evaluation methodology of how to fulfill the research goals. In the first part, the thesis introduces performance measurement application. Secondly the research lists the procedure of analytic hierarchy process (AHP) application to evaluate supply chain performance in the Chinese automotive industry. In the following part, the research clarifies principles of performance measurement and explains framework metrics with formulas. Finally an AHP application based on this research will be demonstrated.

4.1 Performance evaluation application

4.1.1 Performance measurements method selection

As mentioned in chapter 2, many performance measurements methods have been used in evaluation, such as the financial performance measurement system, including the Balanced Scorecard (BSC) (Kaplan and Norton 1992), Results and Determinants by Fitzgerald (1991), performance measurement questionnaires (Dixon, Nanni et al. 1990) and non-financial performance measurement system, including the Input and Output concept by Brown (1996), Performance Of Activity (POA) by Chan and Qi (2003), and other computer aided manufacturing approaches.

However, for the purpose of this research, these performance measurements have a range of limitations or are too uni-dimensional for manufacturing supply chain evaluation. Their limitations include some or all of the following (Shepherd and Gunter 2006):

- They are difficult to apply and adopt, especially some data used in the criteria are difficult to collect, such as the loss of automotive sales and the value of supply chain management;
- They omit the balance of financial and non-financial issues. The objective of automotive supply chain management is to balance operational cost and efficiency, thus it is necessary to integrate financial and non-financial criteria;
- They fail to address the relationship between participant along the supply chain, such as suppliers, manufacturers, retailers, and customers;
- The measurement system is not aligned correctly with strategic goals, company culture or reward systems;
- They encourage short-term optimization by forcing managers to minimize the variances from standards, rather than seek to improve continually;

In order to solve these problems, the research attempts to develop an innovative performance evaluation framework specific for the Chinese automotive industry. The research chooses a specific performance measurement in the form of AHP as the best alternative for evaluating supply chain management in the automotive industry. This alternative has advantages:

1) The design of a manufacturing performance measurement is aimed at monitoring and controlling the correct implementation of the manufacturing operation and strategy (Rangone 1996). Manufacturing performance should be able to assess the overall operations and provide competitive priorities for companies. The automotive supply chain is a complex area and highly unique, and it has many dimensions to be fitted into. Choosing the most suitable alternative, which fulfils the entire set of various metrics, is essential. Thus the research introduces AHP to deal with a set of measures and evaluates the supply chain performance of automotive companies.

2) AHP is a flexible theory of measurement for dealing with quantifiable and intangible criteria (Vargas 1990). Most of the current performance measures fail to clearly distinguish various levels, such as the strategic, tactical, and operational especially in a supply chain (Saad and Patel 2006). AHP breaks the performance measurement system into a hierarchical structure. The research builds an AHP hierarchy structure based on the three main strategic, tactical, operational measures. The hierarchical structure consists of four levels: the evaluation goal, main measures and sub-measures and empirical data, respectively on a top level, middle,

sub-middle and bottom levels.

3) The objectives of the research are to evaluate supply chain performance in the automotive industry and propose suggestions for some improvement for automotive companies. AHP allows the possibility of setting a complex evaluating hierarchical structure, and to undertake comparisons with the importance of each measure's relative to its impact on the evaluating goal. The sensitivity analysis can help automotive managers understand the weakness of their performance and prioritize the areas requiring improvement (Agarwala, Shankara et al. 2006).

With the focus on automotive supply chain management, the industry needs to develop its own specific performance evaluation framework. Meanwhile AHP is an easy and flexible applicable tool to evaluate current Chinese automotive supply chain performance and generate suggestions for supply chain management improvements in the future. Thus the research integrates an innovative evaluation framework with AHP as a very suitable tool for evaluating and analyzing companies' supply chain performance measurement in the automotive industry.

4.1.2 Analytic hierarchy process introduction

AHP is a multicriteria theory of measurement used to derive relative priority scales of absolute numbers from individual judgments. It includes several performance criteria and integrates all financial and non-financial criteria into a single overall performance score of a manufacturing system (Saaty and Alexander 1981; Saaty 1994; Forman 1996; Saaty 2005). In these approaches, the calculation procedure is as follows (Yurdakul 2002; Lin and Hsu 2003):

4.1.2.1 Building an AHP hierarchy

Firstly, the objective of performance measurement is defined, and then criteria, sub-criteria and sample companies are determined. The AHP method divides a complex performance measurement into a hierarchical system of elements. After building the hierarchical structure, pairwise comparisons between criteria are made to establish their weights, which reflect the relative importance of each criterion, and the overall importance of elements are rated.

4.1.2.2 Establishment of pair-wise comparison matrix

After building the hierarchical structure, pairwise comparisons between criteria are made to establish their weights, which reflect the relative importance of each criterion, and the overall importance of elements are rated. Satty's 1-9 scale (see table 4-1) for AHP preference can be used to express the subjective assessment of the relative contribution of criteria to performance objective (Satty 1994; Satty 2005). Thus, the importance of factors is determined.

Table 4- 1: Scale of relative importance

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate value between adjacent scale values

Source: Satty (1994, 2005)

In pairwise comparison, researchers or experts compare two elements and determine the contribution of factors to the result (Saaty 2005). The relative importance of two elements is rated by using a scale with the values 1, 3, 5, 7 and 9. Let $C_1, C_2, \ldots, C_n$ be the set of elements, while a_{ij} represents a quantified researchers and experts' judgment on a pair of elements C_i, C_j. If C_1 is considered "slightly more important" than C_2, "3" points are given to a_{12}. Contrarily, if C_2 is "slightly less important" than C_1, 1/3 point is given to $1/a_{12}$. If C_1 is considered "strongly more important" than C_3, "5" points are given to a_{13}. Contrarily, if C_3 is "strongly less important" than C_1, 1/5 point is given to $1/a_{13}$. Similarly, if C_1 is considered "demonstrably more important" than C_n, "7" points are given to a_{1n}, and 1/7 is given to $1/a_{1n}$ as C_n is "demonstrably less important" than C_1. Then, an n-by-n matrix is yielded as follows:

$$A = [a_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & \cdots & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & \cdots & \vdots \\ \cdots & \cdots & \cdots & 1 & a_{n-1} \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1/a_{n-1} & 1 \end{bmatrix} \end{array} \quad (1)$$

While (1) $a_{ij}>0$

(2) $a_{ij} = 1/a_{ji}, (i\neq j)$

(3) $a_{ii} = 1$ (i, j = 1,2, 3,… ,n.)

4.1.2.3 Eigenvector and eigenvalue calculation

After a pairwise comparison matrix A is structured, then the weights (W_1, W_2,W_3............W_n) of a set of n elements (criteria C_1,C_2, C_3……C_n) and a consistency ratio (CR) can be calculated. The weight of *n* elements (criteria) that reflect the recorded judgments can be obtained by solving for the eigenvector.

Du and Pang (2005) introduced a short and useful computational way to get the eigenvector:

(1) Multiplied elements of each row in matrix A: (2)

$$M_i = \prod_{j=1}^{n} a_{ij}\ , \quad i=1,\ 2,\ 3\ldots\ldots n$$

(2) Calculate the n-th square root of M_i:

$$\overline{W_i} = \sqrt[n]{M_i}$$

(3) If matrix A is a consistency matrix, eigenvector $\overline{W} = \left[\overline{W_1}, \overline{W_2}, \overline{W_3} \ldots\ldots\ldots \overline{W_n}\right]^T$ can be calculated as:

$$W_i = \frac{\overline{W_i}}{\sum_{j=1}^{n} \overline{W_j}}$$

After the eigenvector of the matrix is derived, next is to calculate the eigenvalue which is used to assess the strength of the consistency ratio of the comparative metrics. Satty (1990) developed an equation about consistent matrices. Writing out the system $Aw=\lambda_{max}w$ in detail, an equation of the largest eigenvalue λ_{max} is shown below:

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{W_i}$$

Satty (1994) also suggested that this is a simple way to obtain the maximum eigenvalue λ_{max} (lambda max) when w is available in normalized form. Add the columns of A and take the scalar product of the resulting vector with the vector *w*:

$$\sum_{j=1}^{n} a_{ij} W_j = \lambda_{max} W_i$$

We obtain

$$\sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} W_j = \sum_{j=1}^{n} \left[\sum_{i=1}^{n} a_{ij} \right] W_j = \sum_{i=1}^{n} \lambda_{max} W_i = \lambda_{max}$$

The research takes Du and Pang's (2005) simple formulation to get λ_{max}, showing as:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \tag{3}$$

4.1.2.4 Consistency test

Saaty (1994) proposed utilizing the consistency index (C.I.) and consistency ratio (C.R.) to check the consistency of the comparison matrix.

The consistency index of a matrix of comparison is given by

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4}$$

and C.R. is defined as following:

$$CR = \frac{CI}{RI} \tag{5}$$

The consistency ratio is obtained by forming the ratio of C.I. and the appropriate one of the following set of numbers, each of which is an average random consistency index computed by Forman (1990) which created randomly generated reciprocal matrices using the scale 1/9, 1/8, 1/7...... 1,.......7, 8, 9 and calculate the average of their eigenvalues. This average is used to form the *Random Consistency Index* (R.I.)

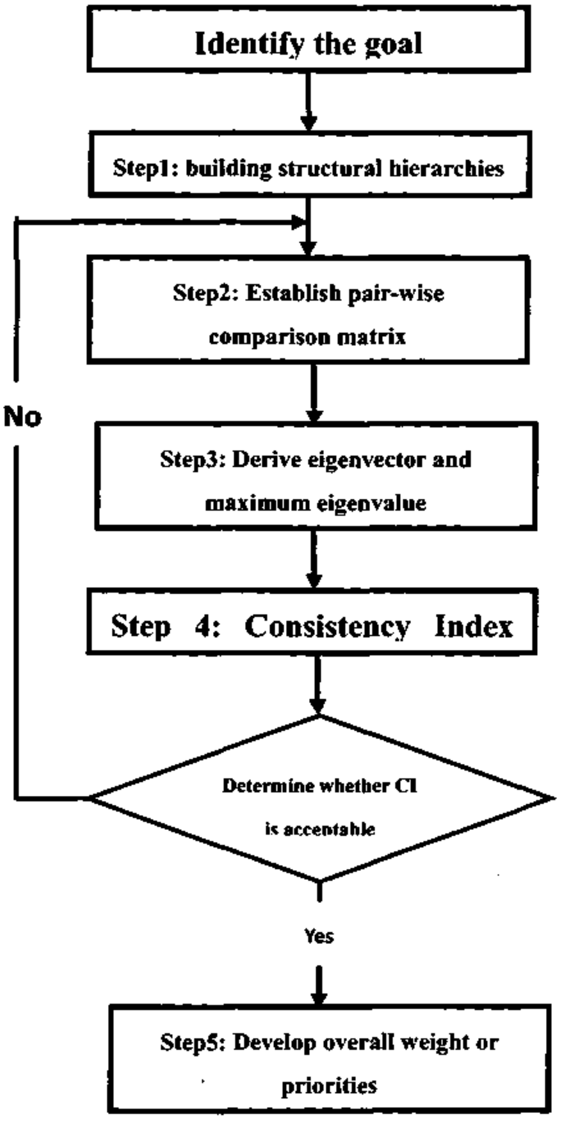
N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
R.I.	**0**	**0**	**.52**	**.89**	**1.11**	**1.25**	**1.35**	**1.40**	**1.45**	**1.49**	**1.51**	**1.54**	**1.56**	**1.57**	**1.58**

R.I. represents the average consistency index over numerous random entries of same order reciprocal matrices. If C.R.< 0.1, the judgments are considered consistent, otherwise if C.R. > 0.1, the judgment may be thought of inconsistent and there may be a need to improve the consistency of the comparison by changing the hierarchy.

4.1.2.5 Calculate final importance

Finally, the AHP combines the relative weights of *n* elements on each level of a hierarchy, and the overall score of performance is presented. The research briefly summaries the main steps of the AHP approach as shown in figure 4-1:

Figure 4- 1: Decision process flowchart for AHP



Source: Liang (2003)

4.2 Performance evaluation procedure

Therefore research applies the analytic hierarchy process (AHP) to measure the performance of supply chain management in the Chinese automotive industry. The details of developing the performance measurement are shown below (see figure 4-2):

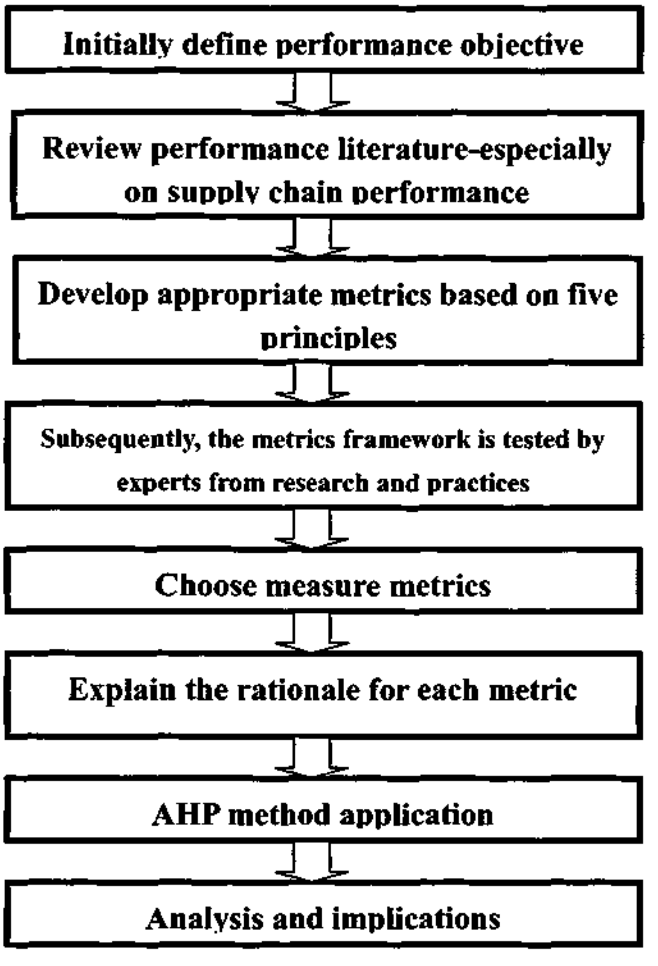
First of all, the objectives of performance measurement need to be defined, which includes deciding what to measure and which areas should be emphasized; then the research reviews the performance measurement literature, especially focusing on the recommendations for designing supply chain performance measurement systems which have been proposed by different authors.

Subsequently a range of appropriate metrics are derived from the literature review. Also the research considers the attitudes from managers who are engaged in the auto industry and experts who are from academic research because they understand this area with their experience and knowledge.

At the third phase the research should explain the reasons for the choice of each performance measure and present measurement formulations. After building a hierarchy of metrics, the AHP method is applied to compare and evaluate several automotive manufacturers from the strategic level, operational level and tactical level.

Finally, in the last section the implications of this research are discussed for the automotive industry and some possible suggestions for improvement are proposed.

Figure 4-2: The framework of analytic hierarchy process application



Source: the author

4.3 Principles of performance measurement

For the purpose of this research, five key principles are highlighted for building an effective AHP evaluation framework. These principles are discussed below in the next section.

4.3.1 Principle 1: Link performance measurement to company's strategy

Performance measurement evaluates operational performance in order to reach defined goals that are derived from the company's strategic objectives (Lohman, Fortuin et al. 2004). The attributes of supply chain performance are identified and performance measures based on the company's strategy selected. An automotive company's strategy is to satisfy the customer and reduce operational cost. Thus the research considers evaluating customer service from the delivery reliability and delivery flexibility points of view, and evaluating financial return for managers' and shareholders from their desired perspective.

4.3.2 Principle 2: Integrate input and output metrics

Traditionally, performance measurement has concentrated on output measures, such as profits and customer satisfaction. However these have failed to connect input and output within the industry (Tan, Platts et al. 2004). The input process central in determining output performance and thus performance measurement should clarify the link between input and output in order to make a systematic operational improvement. Thus the sets of performance measures are defined from input, process and output perspectives. In terms of input perspective, it was considered that advanced facility, technological improvement and innovation, and successful human resource management are "inputs" for efficient supply chain management. In terms of process, this includes supply chain value measure, supply chain time efficiency measure, and equipment utilization measure. In terms of output perspective, the research considers customer service and financial return are efficient supply chain management "outputs". The framework integrates input, process and output metrics which will enable managers to better control business activities.

4.3.3 Principle 3: Support continuous improvement

Continuous improvement as a strategic tool is used by companies to enhance competitiveness. However many companies failed to maximize their supply chain potential because each participant pursues their own independent goals (Lee and Billington 1992). Schroeder et al. (1986) suggested that supply chain performance measurement should be understandable by all supply chain participants and support continuous improvement to ensure minimum costs and maximum opportunity for manipulation.

4.3.4 Principle 4: Performance measures from different perspectives

Globerson (1985) proposed that performance measures should be selected from the people actively involved. Thus the research sets up performance measures according to different perspectives, including customers, employees, managers and shareholders each of whom are involved in the automotive sector. From the customer perspective, as mentioned before, the framework emphasizes supply chain management reliability and flexibility. From the manager perspective, the framework addresses efficient management on asset management and financial development. From the shareholder perspective, the framework evaluates profit return and equity return. And from the employee perspective, the framework considers employee's productivity and welfare.

4.3.5 Principle 5: Balance financial and non-financial metrics

Most companies realize the importance of financial and non-financial performance measurement, however they continue to fail to present a balanced evaluation. Maskell (1991) clarified that financial performance measurements are important for strategic decisions, while non-financial measurement can help better handle day to day operational management. Thus the research attempts to balance a set of financial and non-financial measures at various points of the supply chain which relate to strategic, operational and tactical management.

4.3.6 Summary

Considering the above factors, this research attempts to develop automotive companies' supply chain evaluation framework from these considerations:

Firstly the research attempts to link evaluation framework to a company's strategy. Thus the research defines strategic metrics which are compatible with an automotive company's strategy. Strategic measures are related to the idea of satisfying customers and reducing operational cost. Thus the evaluation approaches from two areas: customer service measures and financial measures.

Secondly, the research connects input and output, and the evaluation framework emphasizes operational process. The operational level evaluates the efficiency of the current automotive manufacturers' supply chain operations. Evaluation metrics include supply chain value measures, efficient time measures and equipment utilization measures.

Thirdly, the research supports a company's continual improvement. The research relates the tactical level evaluation to a company's strategic maintenance and improvement for future development. The framework considers that the main factors necessary for supply chain operations are: facility, technology and employees. In terms of facility, the research evaluates infrastructure investment. In terms of technology, the research evaluates through product improvement and innovation. And in terms of employees, the research evaluates through employee productivity and employee satisfaction.

Fourthly, the research considers different participants' needs. The research evaluates financial measures from both managers and shareholders perspective, and evaluates supply chain performance through delivery reliability and flexibility from customer's perspective. Also the research evaluates salary growth and employee satisfaction from the employees' perspective.

Finally, the research integrates both financial measures and non-financial measures. The financial measures include some commonly used metrics, such as return on asset, net profit and sale growth. And the non-financial measures include metrics related to operational management, such as product cycle time, equipment utilization and new product development.

4.4 Development of framework with metrics

As discussed in previous sections, the research develops a framework from several considerations. Consequently the framework for the automotive supply chain performance evaluation is developed as (See appendix 3):

(1) Strategic measurement: in many manufacturing companies, customer satisfaction is treated as an intermediate strategic goal and financial performance is viewed as a final strategic goal (Vickery, Jayaram et al. 2003). Christopher (1998) indicated that the strategic objective of supply chain management is to reduce cost and

improve service. In the automotive industry, the strategic objective of efficient supply chain management is to offer excellent product and service to customers and provide financial return and profit to managers and shareholders. Therefore, in this research, customer service and company's profits are considered as strategic measures.

(2) Operational measurement: operational evaluation is to assess how efficiency supply chain management can be applied in the manufacturing process. Supply chain operations should balance supply chain cost and product cycle time (Nightingale, Brady et al. 2003; Huang and Zhang 2006). Thus operational measurement assesses current supply chain operations from an operational perspective based on supply chain value and efficiency of cycle time. Otherwise, Lambert (2008) pointed out how efficient processes and other activities in the supply chain affect the final customer and financial performance. Equipment utilization reflects the availability of resource management, optimizing equipment utilization can help to reduce supply chain cost, short delivery time and improve supply chain efficiency, thus utilization of equipment as an appropriate measure is also used in the operational measurement (Chan and Qi 2003).

(3) Tactical measurement: tactical measures support a company's high level efficiency operation and long-term strategy (Kaplan and Norton 1996; Sun, Ma et al. 2004;

Wang and Yuan 2006). The research considers efficient supply chain management should be based on three key elements: facility, technology and employee. Thus tactical measures are approached from infrastructural investment, improvement and innovation, and human resource management. A substantial investment on advanced and professional supply chain equipment and facility can maximize operation and process efficiencies. Consecutive technological improvement and innovation can provide more value-added product and service to satisfy customers and ultimately provide profit to shareholders. Also human resource management can help to improve the level of management, increase the working efficiency, and support managers to be more effective (Joseph and Chang-jun 2009).

The metrics discussed in the research are classified into strategic, operational and tactical measurements. The research assigns metrics to where they can be best dealt with by the appropriate management level and for decision making (Gunasekaran, Patel et al. 2001). In the next section, the metrics and formulas which will be used in the AHP calculation are explained.

4.4.1 Strategic measurement

The fundamental objective of supply chain management is to balance high customer service and low cost (Vickery, Jayaram et al. 2003). Thus the research will assess from an intermediate management perspective: customer service, and a final management perspective: financial measurement.

4.4.1.1 Customer service (C_1)

Customer service may be composed of different dimensions, however customer service typically encompasses delivery performance and the ability to respond to customer requirements quickly and effectively in gaining a competitive advantage for manufacturing companies (Weng 1999). Therefore this research attempts to evaluate delivery performance from two aspects: reliability and flexibility. According to Martin's view (2005), delivery reliability and flexibility is not just reflected in delivery performance, but also reflected stock availability and order processing performance.

D_1 Customer reliability

There are many measures which can be used to evaluate supply chain operational reliability. Considering the Chinese automotive supply chain management is still immature, thus the research evaluates customer reliability from basic questions. These three basic questions are developed from customer basic needs to advanced needs: firstly, if an automotive company is capable of meeting customers' order needs, then if an automotive company is capable of delivering products on-time or before the order time, finally if an automotive company is capable of satisfying customers.

Consequently, reliability performance is measured by the percentage of completed customer orders, on-time delivery and customer satisfaction ratio.

M_1 Percentage of completed order

As mentioned before, completed order is a customer basic need. Some authors, such as Yurdakul (2002) and the balanced scorecard proposed by Kaplan and Norton (1992), used a similar measure of unfulfilled customer order to evaluate customer reliability. In order to easily collect data, the research compares unfulfilled customer order to the percentage of completed order as recommended by Kumar and Ozdamar et al. (2005). Zhao and Li (2008) claimed percentage of completed customer orders during a certain time period can reflect supply chain operational efficiency. The research adopts completed order formulas from Huo and Ma (2002) to evaluate quality of delivery. The research measures percentage of completed order as the percentage of actually completed customer orders to the total customer orders during the time *T* (unit is day).

During the time T, the company received customer orders N times, presuming the time i ($1 \leq i \leq N$), the number of customer orders is $P_{ur}T_i$, and the actual number to fulfill the customer orders is $P_{ro}T_i$, then the equation to calculate the percentage of completed customer orders during the time T can be expressed:

$$P_{co} = \frac{\sum_{i=1}^{N} P_{ro} T_i}{\sum_{i=1}^{N} P_{ur} T_i} \times 100\%$$

Where: P_{co} represents the percentage of completed customer orders in the year T;

$P_{ur}T_i$ represents the customer demand for products in the year T;

$P_{ro}T_i$ represents the actual product number for customers in the year T;

M_2 Percentage of on-time delivery

Stewart (1995) suggested that another important aspect of delivery performance is on-time delivery. On-time delivery is used as the most frequently used measure and it can be affected by many factors, such as customer information shared with suppliers and retailers (Carr and Pearson 1999), just-in-time manufacturing (Karmarkar 1989; Sakakibara, Flynn et al. 1997) and advanced technology and equipment (Ettlie and Reza 1992; Roth 1996).

The research adopts formulas suggested by Zimmermann and Seuring (2009). The research measures on-time delivery by calculating the percentage of on-time deliveries. The on-time delivery includes product delivery on time or before the promised schedule. The equation is stated as below:

$$P_{OTD} = \frac{V_{OTD}}{V_{TD}} \times 100\%$$

Where: P_{OTD} represents the percentage of on-time delivery in the year T;

V_{OTD} represents the number of on-time deliveries in the year T;

V_{TD} represents the total number of product deliveries in the year T;

M_3 Percentage of customer satisfaction

Similar measures are used to evaluate customer reliability include the percentage of customers retained or the percentage of sales loss. The research originally used the percentage of customer complaints recommended by Yurdakul (2002), however during the practical data collection, this had to changed to customer satisfaction in order to simplify data collection. The research defines percentage of customer satisfaction as the ratio of the number of satisfied customers to total customer numbers.

$$P_c = \frac{N_S}{N_{TT}} \times 100\%$$

Where: P_c represents the percentage of customer satisfaction in the year T;

N_s represents the number of satisfied customers in the year T;

N_{TT} represents the total customer numbers in the year T;

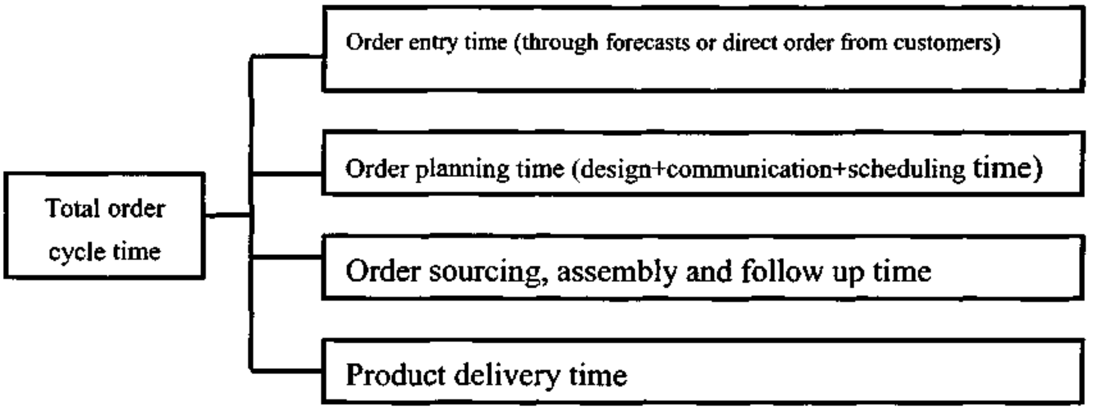
D_2 Customer flexibility

Vokurka and O'Leary-Kelly (2000) emphasized that achieving manufacturing flexibility may add value to customers. Zhang et.al (2002) and Kumar et al.(2006) suggested that manufacturing companies should develop the ability of flexibility to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions or performance losses. Yurdakul (2002) suggested evaluation of a manufacturing system's flexibility in matching changes in customer needs can be approached from product set-up time, product volume or product variety and so on. Thus the research considers performance measurement with regards to customer flexibility from order cycle time, delivery time flexibility and volume flexibility. The research uses order cycle time to identify customer order respond time, and this is used to compare the time which takes the supply chain to respond to customer orders. Delivery time flexibly and volume flexibility are used to evaluate how efficient and effective manufacturers respond to customer time and quantity needs.

M_4 Order cycle time

The measurement of product order cycle time is not only relevant both in the context of customer service, but also serves as a feedback to control the operations (Schonberger 1990). Similar measures to evaluate product order cycle time included product delivery time (Yurdakul 2002) and customer query time (Bigliardi and Bottani 2010). Order cycle time in this research was defined as the lead time between receipt of customer order and final delivery of the goods, and includes the following time elements (Christopher 1992; Vickery, Droge et al. 1997; Gunasekaran, Patel et al. 2001) (Showing in Figure 4-3):

Figure 4- 3: Order cycle time elements



Source: Christopher (1992); Vickery and Droge el.al (1997); Gunasekaran and Patel et al. (2001)

The research selects the simple way to evaluate the average cycle time to respond to a customer order during year T by using the formula:

$$\overline{OC^T} = \frac{1}{N}\sum_{i=1}^{N} T_{oci}$$

Where:

T_{oci} represents each cycle time to response to different customer orders during period T;

M_5 Slack time of vehicle delivery

The slack time of vehicle delivery reflects how well the supply chain can respond to customers' requirements (Carr and Pearson 1999). The research used an equation recommended by Huo and Ma (2002). The equation evaluating the average slack time of vehicle delivery can be expressed by:

Presuming t^* is the average vehicle delivery time, L_j is the longest time for vehicle delivery, E_j is the shortest time for vehicle delivery, for J customers (J=1, 2, 3.....j), the total slack time is calculated as:

$$TST = \sum_{j=1}^{J} \left(L_j - t^* \right)$$

For J customers, the total shortest time is calculated as:

$$T_s = \sum_{j=1}^{J} \left(E_j - t^* \right)$$

So the flexibility for the time of vehicle delivery can be expressed as:

$$ST = \frac{\sum_{j=1}^{J} \left(\left(L_j - t^* \right) - \left(E_j - t^* \right) \right)}{\sum_{j=1}^{J} \left(L_j - t^* \right)}$$

$$ST = \frac{\sum_{j=1}^{J}(L_j - E_j)}{\sum_{j=1}^{J}(L_j - t^*)}$$

M_6 Vehicle volume flexibility

Huo and Ma (2002) described vehicle volume flexibility to evaluate adaptability of a manufacturing system to match their product to the customer needs. Vehicle volume flexibility refers to the ratio of manufacturer's productivity to market demand. The research adopts a formula from Huo and Ma (2002), and is stated as:

$$R_{VF} = \frac{V_{mau}}{D_{mar}} \times 100\%$$

Where: R_{VF} represents the percentage of manufacturer's productivity to the total market demand in the year T;

V_{mau} represents the number of vehicles that was produced by manufacturers in the year T;

D_{mar} represents the total number for market demand in the year T;

4.4.1.2 Financial measurement (C2)

Financial performance is concerned with both the perspectives of operation managers and the company's shareholders. There are a number of financial measures which can be used in this research, however, considering most financial data are confidential, many automotive companies are reluctant to release financial information. Thus in order to collect data, the research only chooses financial measures that are publicized on the company's annual report. The research captures a set of financial performance measures which provide important implications for shareholders, such as pre-tax return on assets (ROA) and sales growth rate. The research also captures a set of non-financial performance measures which provide important implications for managers, such as asset turnover ratio and stock turnover ratio. Financial measures are accessed from two perspectives: manager's perspective and shareholder perspective. In terms of manager's perspective, the research firstly evaluates an automotive company's profitability by using a measure of return on assets. Then the research evaluates how efficiently current supply chain management is in coordinating the use of its assets, such as relative to asset turnover and stock turnover and how well it affects sales and profit growth. From a shareholder's perspective, the research mainly focuses on evaluating how well a company generates profit to shareholders. Net profit margin and return on equity are considered appropriate because they are directly reflecting the profitability for shareholders.

D_3 From the manager's perspective

Gunasekaran et. al (2004) observed that supply chain assets include accounts plant, property, equipment, and inventories. With increasing economic inflation and decreased current liquidity, the company has to improve the productivity of capital and facilities to minimize the cost associated with each asset. Thus the research evaluates performance from the following:

M_7 Return on assets

Keebler and Plank (2009) indicated pre-tax return on assets (ROA) is commonly used to measure a company's ability to produce net profits by effectively utilizing its assets. The higher the ratio, the more effective the company is at using its assets to produce profits (Kauffman 2006). Brewer and Thomas W (2000) described the return on supply chain assets calculated by dividing consumer profitability by the average company assets deployed during the period. The research defines return on assets is calculated by dividing pre-tax revenue by average assets in the year T.

$$R_{roa} = \frac{RE_{end} - RE_{sta}}{\frac{TAsset_{sta} + TAsset_{end}}{2}} \times 100\%$$

Where: RE_{end} represents the final pre-tax revenue in the year T;

RE_{sta} represents the initial pre-tax revenue in the year T;

$TAsset_{sta}$ represents the initial total assets in the year T;

$TAsset_{end}$ represents the final total assets in the year T;

Asset operations

Asset operations measures evaluate how efficiently a company's assets are used during operation. The research evaluates asset utilization from total asset turnover ratio and stock turnover. Asset utilization indicates the efficiency of a company's management on asset utilization. And stock turnover indicates the level of inventory management.

M_8 Total asset turnover ratio

This is a measure of how well assets are being used to produce revenue. The higher the measure, the more efficient the operation management (Investorworld 2006). The research accepts Bian and Liu et al's (2007) recommendation and defines total asset turnover ratio (ATO) as a company's net sales divided by its total assets.

$$R_{ato} = \frac{NS}{\frac{TAsset_{sta} + TAsset_{end}}{2}} \times 100\%$$

Where: NS represents a manufacturer's net sale in the year T;

$TAsset_{sta}$ represents the initial total assets in the year T;

$TAsset_{end}$ represents the final total assets in the year T;

M_9 Stock turnover ratio

Slack, Chambers et al. (1995) indicated effective management of inventory in the supply chain is crucial for customer service quality. Some researchers used inventory measures to evaluate customer service, such as number of inventory turns proposed by

Bigliardi and Bottani (2010). Stock turnover ratio evaluation used in this research is to measure the efficiency of inventory management in an automotive company. The company's inventory policy, volume and stock location clearly influence the size of total inventory (Martin 2005). Stock turnover ratio shows how well inventory is managed by calculating the inventory turnover times during a fiscal year. This ratio is helpful in evaluating under-stocking, overstocking, stock obsolescence and the need for inventory improvement. The quicker stock is turned over indicates the greater the sales and the greater profit (AIB 2006). The research adopts the formulas from Bian and Liu et al.'s (2007) research and measures stock turnover ratio by dividing the annual sales by average stock in the year T.

$$R_{sto} = \frac{S^T}{\sum_{i=1}^{N} S_{tock} / N} \times 100\%$$

Where: S^T represents the sale of vehicle units in the year T;

Financial development capability

Financial development capability indicates a company's business and financial potential, and helps the company to improve operations and plan for the future. The research evaluates automotive manufacturers from auto sales growth rate and profit growth rate. According to Chan and Qi (2003), outcomes of supply chain activities and process are to add value to products and services. Similar measures used to evaluate financial development capability includes growth in market share that was proposed by Sahay, Gupta et al. (2006). However the research finally selects auto sales growth and profit growth because they are typical and more common used to reflect the ability of supply chain management and the effect of a company's strategies and planning.

M_{10} Auto sales growth rate

Annual sales growth rate measures the rate of change in a company's annual sales. Much research has linked product sales growth to product profitability, as it helps to improve operating efficiency and maintain market share (Kauffman 2006). Thus the research defines the formula of auto sales growth rate as:

$$R_{sale} = \frac{S^{T} - S^{T-1}}{S^{T-1}} \times 100\%$$

Where: S^{T} represents the sale of vehicle units in the year T;

S^{T-1} represents the sale of vehicle units in the previous year T-1;

M_{11} Profit growth rate

Annual profit growth rate is used in the analysis of product sales forecasting, and identifies the company's development capability (He and Zhang 2004; Yin and Zhang 2005). The research defines the formula of profit growth rate as:

$$R_{profit} = \frac{P^{T} - P^{T-1}}{P^{T-1}} \times 100\%$$

Where: P^T represents the profit of manufacturers in the year T;

P^{T-1} represents the profit of manufacturers in the previous year T-1;

D_4 From the shareholder's perspective

Martin (2005) suggested that performance measures should also concern shareholder value. From a shareholders' viewpoint, cost is a necessary aspect in accessing the performance of the business activities and process. The research chooses two economic indicators which are frequently being used to measure shareholder value, namely net profit margin and return on equity (ROE). These metrics evaluate the effectiveness of cost control based on recording operation inputs and output.

M_{12} Net profit margin

Chia and Goh et al. (2009) described net profit margin as one of the most commonly used measures in financial evaluation, and similar measures include profit before tax. Net profit margin is an indication of how effective a company is at cost control, assuming that the higher the net profit margin is, the more effective the company is at converting revenue into actual profit. The net profit margin is a good way of comparing companies in the same industry (Investor Words 2008). Here the research adopts formulas from Chia and Goh et al. (2009) and measures net profit margin ratio by dividing the net profit by the annual sales revenue in the year T:

$$P_{mar} = \frac{P_{net}}{R_{sale}} \times 100\%$$

Where: P_{net} represents a manufacturer's net profit in the year T;

R_{sale} represents a manufacturer's sales revenue in the year T;

M_{13} Return on equity

There are a number of well-known financial measures such as return on investment (ROI), return on equity (ROE) and return on asset (ROA) which can be used in this research, however the research only select return on equity (ROE) because it is available on the company's annual report. Return on equity (ROE) measures the value a company has created for its stockholders (Stewart 2006). It is used as a general indication of the company's efficiency, in other words, it determines how much profit is able to be created by using equity which is provided by stockholders. ROE used in this is equal to a fiscal year's pre-tax revenue divided by total equity investment, expressed as:

$$R_{roe} = \frac{RE_{end} - RE_{sta}}{\frac{TEquity_{sta} + TEquity_{end}}{2}}$$

Where: RE_{end} represents the final pre-tax revenue in the year T;

RE_{sta} represents the initial pre-tax revenue in the year T;

$TEquity_{sta}$ represents the initial total equity investment in the year T;

$TEquity_{end}$ represents the final total equity investment in the year T;

4.4.2 Operational measurement

The research evaluates supply chain operations from three perspectives: supply chain value, efficiency of lead time and equipment utilization. As mentioned in the previous part, the efficiency of a supply chain can be evaluated by using the supply chain cost and time. Product cycle time and cost are important advantages in the modern business environment, especially during customer order driven supply chain systems in the automotive industry. Also equipment utilization plays an important role in supply chain operation and its evaluation result can provide valuable feedback that can be used to improve supply chain performance on efficiency and effectiveness.

4.4.2.1 From a value perspective (C3)

Originally the research used supply chain value added ratio to evaluate how much value is created by the supply chain. The calculation is expressed by dividing supply chain value by supply chain cost. However during practical data collection, the research needs to collect financial data from suppliers, manufacturing and retailers. The collection procedure is long and difficult, thus had to be abandoned. Finally the research accepts Kumar and Ozdamar et al. (2005) recommended using supply chain cost to evaluate supply chain value.

M_{14} Supply chain cost ratio

Managers who want to reduce product cost and satisfy customers need to be more concerned with supply chain management. Many factors can result in significant supply chain cost, such as holding high inventory, frequent transport delivery, high material procurement, amount of equipment and facility investment (Gua 2005; Huang and Zhang 2006). How to implement a flexible supply chain strategy to reduce cost are issues commonly faced by managers. The research attempts to measure supply chain performance from a value perspective by using supply chain cost ratio. Kumar and Ozdamar et al. (2005) described the formulas of the supply chain cost equal to product sale by product cost. However product cost is commonly considered confidential by business. Consequently the research uses the formulas proposed by Chao, Xue et al. (2007), where the supply chain cost can be calculated by dividing supply chain cost by total sales in the year T. The formula is expressed as:

$$P_{cost} = \frac{SC_{cost}}{TS} \times 100\%$$

Where: SCcost represents the supply chain cost in the year T;

TS represents the total sales in the year T;

4.4.2.2 From a time perspective (C4)

M_{15} Efficiency of time

In today's markets, the speed of response to customer demands is a key competitive advantage. Customers only care about the total cycle time from demanding to receiving the vehicle and they are unimpressed by a short manufacturing time if the other parts of the delivery chain make response time slow.

In general, the product cycle time may be divided into value activity time (NV) and non-value activity time (NVA). Value activity time means manufacturing operations time, and non-value activity time is the time between manufacturing operations, such as materials handling, product quality inspections, inventories, waiting or rework (Blackburn 1992).

In this research, product delivery time refers to the time from receipt of customer orders until the product is received by customers. This research agrees with Kumar and Ozdamar et al.'s (2005) description of measuring the efficiency of responding to customer demand by using the ratio of ideal delivery time to average delivery time in reality.

$$R_{dt} = \frac{\mathrm{DT_{id}}}{\sum_{i=1}^{N} DT_{veh} / N}$$

Where: DT_{id} represents the ideal product delivery time to customers in the year T;

DT_{veh} represents the product delivery time to customers in the year T;

4.4.2.3 From equipment utilization perspective (C5)

Equipment utilization rate is also called the "operating rate". It indicates how much a company's installed equipment has been actually used over a period of time. It refers to the relationship between actual produced output and potential output that could be produced with the installed equipment (Fang, Li et al. 2007).

Equipment utilization rate is one of the most important measurements in a supply chain operation, as it impacts upon various other activities, such as preventive maintenance, asset replacement planning, driver reimbursement costs, delivery truck size and composition, budgeting and so on. According to Slack et al. (1995), optimizing equipment utilization can help manufacturers to increase product cycle time and produce costs, improve customer satisfaction, and gain in flexible deliverability. Since transport management and warehouse management are closely linked to supply chain management, they make significant the impact upon supply chain cost (Cavinato 1992). Thus for the purpose here, the research considers to assess equipment utilization from two issues: transport capacity utilization ratio and warehouse capacity utilization ratio.

M_{16} Transport capacity utilization ratio

Transport capacity utilization is being developed by some supply chain researchers used as a measure of efficient transportation practice (Sarkar and Mohapatra 2008). In order to cut costs, maximizing the utilization of transport capacity is being used by many manufacturers. Every mode of transport has a standard loading capacity, which is defined by the weight or the volume of the product. To determine how well the capacity of transport in the Chinese automotive industry is used, the research classified trucks as heavy-loading, light-loading and average product-loading. Subsequently the research used the average product-loading truck as an example, and the transport capacity utilization ratio can be calculated by dividing the average practical truck capacity by the standard truck capacity (Wang and Chi 2004):

$$R_{tcu} = \frac{\sum_{i=1}^{N} P_{tcu} / N}{ST_{tcu}} \times 100\%$$

Where: P_{tcu} represents the practical truck' s capability in the period T;

ST_{tcu} represents the standard truck's capacity in the period T;

M_{17} Warehouse capacity utilization ratio

The optimal utilization of storage capacity is a key issue for manufacturers with undersized warehouses, especially in situations where storage areas are expensive.

There are several factors that can influence warehouse capacity utilization, such as package size, storage design, storage pallets and racks and so on. Better utilization of storage space can increase product storage area and reduce inventory cost (Nightingale, Brady et al. 2003). The research accepts Wang and Chi's (2004) suggestion and evaluates warehouse utilization by using the ratio of actual used storage area to the total storage area over the time. The equation is shown as:

$$R_{wcu} = \frac{Act_{area}}{Tot_{area}} \times 100\%$$

Where:

R_{wcu} represents the ratio of warehouse capacity utilization ratio in the period T;

Act_{area} represents the actual storage area for completed products in the period T;

Tot_{area} represents the total storage area for completed products in the period T;

4.4.3 Tactical measurement

Tactical measurement is considered to evaluate supply chain operations which are crucial for long-term financial and customer strategies. Kaplan and Norton (1996) stated continuous improvement and innovation are important for a company's future development. Infrastructure investment and human resource management are essential for manufacturers to achieve success. Thus the research attempts to approach tactical measures from three main perspectives: hardware perspective, technology perspective and software perspective. In terms of hardware perspective, the research will evaluate a company's investment on supply chain operational infrastructure. In terms of technology perspective, the research will evaluate from a company's technology improvement and innovation. Final in terms of software, the research evaluation focuses on human resource management, such as employees' satisfaction ratio.

4.4.3.1 Infrastructural investment (C6)

M_{18} Infrastructural investment

Infrastructural investment measurement stresses the importance of infrastructural investment for the future of the supply chain, such as new equipment, new facilities and new technology. Wang and Yuan (2006) suggested that infrastructural investment can be applied to reduce the lead time and improve product quality and operational performance. It also helps to achieve ambitious long-term financial growth. Wang and Yuan (2006) recommended the simple way to evaluate the rate of infrastructural investment as:

$$R_{infra} = \frac{V_{infra}}{P^{T}\text{-}P^{T-1}} \times 100\%$$

Where: V_{infra} represents the investment on supply chain infrastructure in the year T;

P^T represents the profit of manufacturers in the year T;

P^{T-1} represents the profit of manufacturers in the previous year T-1;

4.4.3.2 Improvement and innovation (C7)

Traditional financial measures encourage managers to adopt a short-term sales figure instead of considering operational continuous improvement and innovation. Metrics of improvement and innovation evaluate a manufacturer's capability of implementing technology research and applying research improvement and innovation to ensure a company remains competitive and retain its customers. New product development is used as a direct measure to evaluate the result of technology improvement and innovation, and employee training ratio is a simple measure to assess implementation of improvement and innovation. Thus the research will evaluate tactical development from two perspectives: new product development and employee training rate.

M_{19} New Product development

Some researchers used new product development to evaluate supply chain customer service, such as a metric of new product introduction proposed by Agarwal and Shankar (2002) or used new product development to evaluate supply chain competitiveness, such as new product development presented by Sahay and Gupta et al. (2006). In this research, new product development is used to measure a company's capability of developing new products to meet customer demands. Thus new product development flexibility is measured by the ratio of making new vehicle models to total models. Considering the automotive industry is under heavy competition, vehicle models are rapidly out-of-date and are upgraded frequently. The research expressed the equation as dividing the new product models to the average total vehicle models:

$$P_{PF} = \frac{Q_{NP}}{(Q_{STP} + Q_{ETP})/2} \times 100\%$$

Where: P_{PF} represents the percentage of new vehicle product to the total vehicle models in the year T;

Q_{NP} represents the number of new vehicle models in the year T, new vehicle models included newly introduced vehicles, newly developed vehicles, redefined vehicle models, new hybrid vehicle and so on;

Q_{STP} represents the initial total number of vehicle models in the year T;

Q_{ETP} represents the final total number of vehicle models in the year T;

M_{20} Employee training rate

Nowadays, manufacturers in the auto industry have replaced almost all routine work by computer-controlled manufacturing operations for manufacturing, processing and assembly (Sun, Ma et al. 2004). Therefore encouraging and facilitating employees to engage in education and training are important for management. In order to evaluate employee training rates, Kumar and Ozdamar et al. (2005) proposed the training utilization rate and Chia and Goh et al. (2009) investment in employee training. Kumar and Ozdamar et al. (2005) described employee training rate by using the ratio of number of training places utilized compared with the number of planned training places over time. It is difficult to define the concept of training utilization during the investigation. Chia and Goh et al. (2009) evaluated employee training by using investment in employee training, however, in the Chinese automotive industry, there is no specific financial data regarding training investment.

Finally the research evaluated employee education and training by calculating the average education and training time spent on each employee during the period r. This formula has advantages as: firstly it is easier to collect data, secondly the formula emphasizes how much training time there is for employees and its effectiveness. The formulation can be expressed by dividing the total time of training and education programmes by the total working time of employees:

$$R_{et} = \frac{\sum_{i=1}^{N} T_{tp}}{T_{employee}} \times 100\%$$

Where: R_{et} represents employee's training rate in the period r;

$T_{employee}$ represents the working time of employees in the period r;

4.4.3.3 Human resource management (C8)

In this part, the research attempts to evaluate human resource management from three perspectives, namely: employee productivity, salary growth rate and employee satisfaction ratio. Chow and Heaver et al. (1994) indicated the use of input-output ratios, also known as productivity, is commonly used in supply chain performance evaluation. Input/output measures have advantages as they can be used to evaluate goal attainment in many areas. Employee productivity is used in this research as an outcome measure to indicate how much output can be generated by each employee. Employee productivity is a direct measure to reflect how successfully human resource management is transformed into financial outputs. Then the research considers how employee salary growth can significantly link to employee productivity. It can provoke employees to being more efficient and effective. Also Chia and Goh et al. (2009) insisted employee satisfaction ratio is the most frequently measured indicator under the human resource management perspective. Employee satisfaction ratio is particularly useful for performance because it directly reflects effective human resource management. Consequently the research will evaluate employee productivity, salary growth rate and employee satisfaction ratio.

M_{21} Employee productivity

Kaplan and Norton (1996) stressed that employee productivity has the aggregate impact of satisfying customers. Liu and Yan (2006) described the simplest is to measure productivity by calculating each employee's revenue, however, this measure has some limitations. For example, one problem is that the cost associated with the revenue is not included, so revenue of each employee can increase while the company's profits decrease. Therefore another way to measure employee productivity is taken which is to measure the value-added of each employee. The research expresses the equation as shown below:

$$R_{ep} = \frac{R_{evnue} - C_{ost}}{N_{employee}} \times 100\%$$

Where: R_{evnue} represents a company's revenue in the year T;

C_{ost} represents company's costs in the year T, including operational cost, material cost and employees' salary and so on;

$N_{employee}$ represents the number of employees in the year T;

M_{22} Salary growth rate

There are various factors that lead to employee satisfaction such as opportunity for personal growth, adequate authority, an interesting and challenging job, appreciation of work, good working conditions and so on. However salary growth is a major factor that affects employee satisfaction. Fair rewards can give employee motivation and stimulate employee's internal potential (Zhang 2005; Wu and Chen 2009). The research calculates an average salary growth in a company as:

$$R_{sg} = \frac{S^T - S^{T-1}}{S^{T-1}} \times 100\%$$

Where: R_{sg} represents the rate of average salary growth in year T;

S^T represents a company's average employee salary in year of T;

S^{T-1} represents a company's average employee salary in the year of T-1;

M_{23} Employee satisfaction ratio

Employee satisfaction is a fundamental ingredient for success of human resource management. In today's environment it is important for a company to retain their employees. Some researchers, such as Chia and Goh et al. (2009) used employee turnover every year to evaluate employee satisfaction. Higher retention rates means employees are more loyal and committed to the company, employees with higher job satisfaction care more about the quality of their work and create a higher-performance (Pao and Xiao 2007; Song 2007). In order to capture most information on employee satisfaction, the research finally selects employee satisfaction ratio. This is measured by dividing the satisfied employee[7] numbers by total employee number, and the equation is expressed as:

[7] The research measure employee satisfaction using the 5 point scale "Extremely satisfied", "Very satisfied", "Somewhat satisfied" "Not very satisfied" and "Not at all satisfied"

$$P_{es} = \frac{S_{employee}}{TN_{employee}} \times 100\%$$

Where: $S_{employee}$ represents the number of satisfied employees in the year T, and satisfied include extremely satisfied, very satisfied, and somewhat satisfied employees;

$TN_{employee}$ represents the total number of employees in the year T;

4.4.3.4 Summary

Finally, the research summarizes 23 measures and their formulas from strategic, operational and tactical perspectives. The details are listed in Table 4-2, Table 4-3 and Table 4-4:

Table 4- 2: Strategic measures and formulas

Customer service measurement

	Metrics	Descriptions	Related literature	Formulas
Reliability	**M_1 Percentage of completed order**	The ratio of the completed orders to total orders	Yurdakul (2002); Zhao and Li (2008); Kumar and Ozdamar et al. (2005); Huo and Ma (2002);	$P_{co} = \frac{\sum_{i=1}^{N} P_{ro}T_i}{\sum_{i=1}^{N} P_{ur}T_i} \times 100\%$
	M_2 Percentage of on-time delivery	The percentage of delivering on or before the promised schedule	Stewart (1997); Wacker (1996); Carr and Pearson (1999); Karmarkar (1989); Sakakibara et. al (1997); Ettlie and Reza (1992); Roth (1996); Zimmermann and Seuring (2009);	$P_{OTD} = \frac{V_{OTD}}{V_{TD}} \times 100\%$
	M_3 Percentage of customer satisfaction	The ratio of satisfied customer number to total trade number	Yurdakul (2002)	$P_c = \frac{N_S}{N_{TT}} \times 100\%$
Flexibility	**M_4 Order cycle time**	The average cycle time to respond to customer order	Schonberger (1990); Vickery et. al (1997); Bigliardi and Bottani (2010);Christoper (1992); Schonberger (1990) ; Droge et al. (1997); Patel et al. (2001)	$\overline{OC^T} = \frac{1}{N}\sum_{i=1}^{N} T_{oci}$
	M_5 Delivery slack time	The average slack time of vehicle delivery	Wacker (1996); Carr and Pearson(1999); Karmarkar (1989) ; Sakakibara et. al (1997)	$ST = \frac{\sum_{j=1}^{J}(L_j - E_j)}{\sum_{j=1}^{J}(L_j - t^*)}$
	M_6 Volume flexibility	The measures indicate manufacturer's productivity	Huo and Ma (2002)	$R_{VF} = \frac{V_{mau}}{D_{mar}} \times 100\%$

Source: the author

Financial measurement

	Metrics	Descriptions	Related Literature	Formulas
From manager's perspective	**M_7 Return on assets**	ROA measures a company's ability to produce profits.	Gunasekaran et. al (2004); Keebler and Plank (2009); Brewer and Thomas W (2000); Kauffman (2006); Stewart (1995)	$R_{roa}=\frac{RE_{end}-RE_{sta}}{\frac{TAsset_{sta}+TAsset_{end}}{2}}\times 100\%$
	M_8 Total asset turnover ratio	ATO measures how well assets are being used to produce revenue	Invest world (2006); Bian and Liu (2007); Martin (2005)	$R_{ato}=\frac{NS}{\frac{TAsset_{sta}+TAsset_{end}}{2}}\times 100\%$
	M_9 Stock turnover ratio	It shows how well inventory is managed	Martin (2005); Slack et. al (1995); Lee and Billington (1992); Stewart (1995); Christopher (2005); Levy (1997); Bigliardi and Botani (2010); AIB (2006)	$R_{sto}=\frac{S^T}{\sum_{i=1}^{N} S_{tock}/N}\times 100\%$
	M_{10} Auto sales growth rate	It measures the rate of change in auto company's annual sales	Sahay and Gupta et al. (2006); Kauffman (2006)	$R_{sale}=\frac{S^T-S^{T-1}}{S^{T-1}}\times 100\%$
	M_{11} Profit growth rate	It identifies the auto company development capability	Sahay and Gupta et al. (2006); He and Zhang (2004); Yin and Zhang (2005)	$R_{profit}=\frac{P^T-P^{T-1}}{P^{T-1}}\times 100\%$
From shareholder's perspective	**M_{12} Net profit margin**	It measures how effective a company is making profit	Martin (2005); Chia and Goh et. al. (2009); Wikipedia (2007); Investor word (2008)	$P_{mar}=\frac{P_{net}}{R_{sale}}\times 100\%$
	M_{13} Return on equity	ROE measures the value created for stockholders	Stewart (2006)	$R_{roe}=\frac{RE_{end}-RE_{sta}}{\frac{TEquity_{sta}+TEquity_{end}}{2}}$

Source: the author

Table 4- 3: Operational measures and formulas

	Metrics	Descriptions	Related Literature	Formulas
Operational measurement	**M_{14} Supply chain cost ratio**	It evaluates supply chain cost	Gua (2005); Huang and Zhang (2006); Kumar and Ozdamar (2005); Chao and Xue et al. (2007)	$P_{cost} = \frac{SC_{cost}}{TS} \times 100\%$
	M_{15} Efficiency of lead time	It measures the efficiency of lead time based on NV and NVA	Blackburn (1992); Kumar and Ozdamar (2005)	$R_{dt} = \frac{DT_{id}}{\sum_{i=1}^{N} DT_{veh} / N}$
	M_{16} Transport utilization ratio	It measures the transport capacity	Cavinato (1992); Sarkar and Mohapatra (2008); Wang and Chi (2004)	$R_{tcu} = \frac{\sum_{i=1}^{N} P_{tcu} / N}{ST_{tcu}} \times 100\%$
	M_{17} Warehouse utilization ratio	It evaluates warehouse utilization	Cavinato (1992); Nightingale and Brady et. al (2003); Wang and Chi (2004)	$R_{wcu} = \frac{Act_{area}}{Tot_{area}} \times 100\%$

Source: the author

Table 4- 4: Tactical measures and formulas

	Metrics	Descriptions	Related Literature	Formulas
Investment	**M_{18} Infrastructural investment**	It evaluates a company's infrastructural investment	Wang and Yuan (2006)	$R_{infra} = \frac{V_{infra}}{P^T - P^{T-1}} \times 100\%$
Improvement	**M_{19} New product development**	It measures capability of developing new products	Agarwal and Shankar (2002); Sahay and Gupta et al. (2006); Vokurka and O'Leary-Kelly (2000)	$P_{PF} = \frac{Q_{NP}}{(Q_{STP} + Q_{ETP})/2} \times 100\%$
	M_{20} Employee training rate	It evaluates employee training and education	Kumar and Ozdamar et al. (2005) ; Chia and Goh et al. (2009); Garvin (1991); Sun and Ma et al. (2004)	$R_{et} = \frac{\sum_{i=1}^{N} T_{tp}}{T_{employee}} \times 100\%$
Human resource management	**M_{21} Employee productivity**	It indicates how much output can be generated by each employee	Kaplan and Norton (1996); Liu and Yan (2006)	$R_{ep} = \frac{R_{evnue} - C_{ost}}{N_{employee}} \times 100\%$
	M_{22} Salary growth	It evaluates employees' salary growth	Zhang (2005); Wu and Chen (2009)	$R_{sg} = \frac{S^T - S^{T-1}}{S^{T-1}} \times 100\%$
	M_{23} Employee satisfaction ratio	It measures employee's satisfaction	Chia and Goh et al. (2009); Pao and Xiao (2007); Song (2007)	$P_{es} = \frac{S_{employee}}{TN_{employee}} \times 100\%$

Source: the author

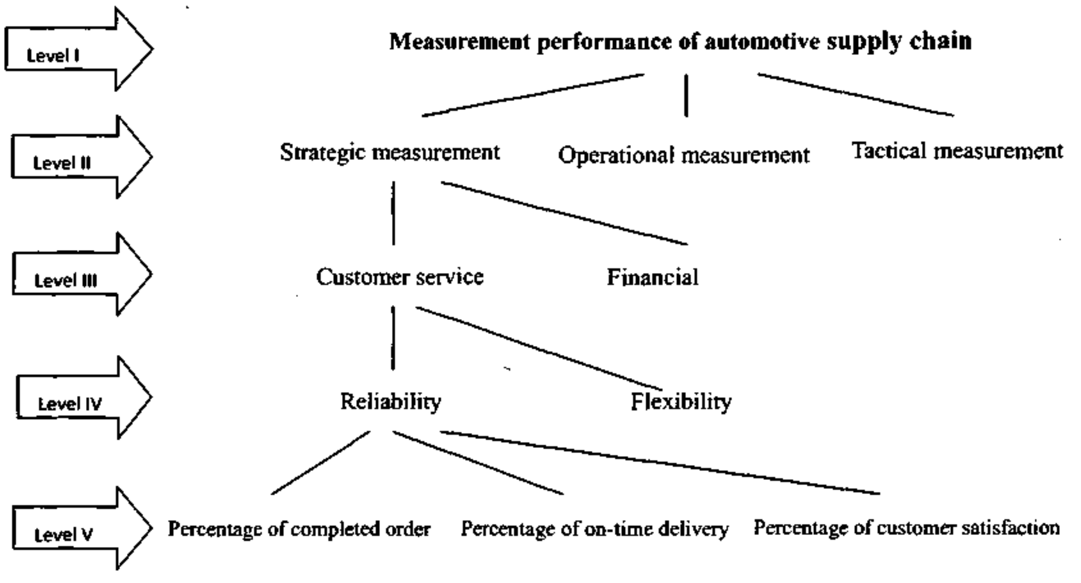
4.5 AHP application based on this research

This section will demonstrate an AHP methodology which has been selected as the best option to apply to evaluate supply chain performance in the automotive industry. There are five major steps which are as follows:

4.5.1 Step 1: Constructing the hierarchical model

The first step is to identify critical factors that have a major impact on the success of automotive supply chain performance. Three critical factors include strategic performance, operational performance and tactical performance. All the critical factors for successful supply chain management are then sub-divided into sub-critical success factors which were verified by experts and managers in the automotive industry. The strategic measures sector was further classified into customer service and financial measurement, and operational measures comprise supply chain value, efficiency of lead time, and equipment utilization; tactical measurements include three aspects, namely infrastructure investment, improvement and innovation, and human resource management. Then sub-sub factors can be classified in the same way. Figure 4-3 shows the hierarchical framework for performance measurement in the automotive industry, The first level (Level I) identifies the goal of AHP for measuring supply chain performance, the second level (Level II) identifies the strategic measurement, operational measurement and tactical measurement of the entire system, while the third level (Level III) identifies the critical success sub-factors with respect to the strategic, operational and tactical measurement. The fourth level (Level IV) identifies the critical success sub-sub-factors for automotive manufacture performance measurement. The final level (Level V) consists of empirical data which has been collected from sample automotive companies in China. The conceptual framework of performance measurement is shown in figure 4-4:

Figure 4- 4: The conceptual framework of performance measurement



Source: The author

4.5.2 Step 2: Performing paired comparisons

The research builds paired comparisons as following:

(1) Comparisons of critical factor

Firstly, the research presents paired comparisons of the critical factors that influence performance measurement. The application of this step in the example is shown in Table 4-5. A pair-wise comparison matrix is constructed and solved for its principal eigenvector[8], denoted as *A*, as an outcome of this step.

[8] Similar name: weighted priority or e-vector

Table 4- 5: Pair-wise comparison and normalized matrix of the factors

PM Factors (A)	Strategic (B_1)	Operational (B_2)	Tactical (B_3)	Overall importance[9]
Strategic (B_1)	1	a	b	---
Operational (B_2)	1/a	1	c	---
Tactical (B_3)	1/b	1/c	1	—

Source: The author

As shown from the paired comparison matrix A, alphabet "a", "b", "c" represent 1-9 scale which used to express expert's judgment. Assume strategic factor B_1 is moderately more important than operational factor B_2, scale "a" is given. Contrarily, B_2 is moderately less important than strategic factor B_1, the reciprocal of "a", scale 1/a is given. Similarly if strategic factor B_1 is strongly important than tactical factor B_3, scale "b" is given. Contrarily, tactical factor B_3 is strongly less important than strategic factor B_1, the reciprocal of "c", scale 1/c is given.

(2) Comparisons of sub-factors and sub-sub critical factors

Secondly, the research presents and compares sub-factors according to their influence on the critical factors (see Table 4-5). The relative effects of each criterion towards the overall performance measurement are considered. For each criterion, a pairwise comparison matrix is constructed and principal eigenvector of each individual matrix is obtained. These principal eigenvectors represent the dependencies (effects) among

[9] Similar name: weight or e-vector

criteria. These effects are denoted by *B*, and the effect of criterion *i* to criterion *j* is shown as $B_i \rightarrow B_j$ (take an example of B_1 which is shown in Table 4-6). Sequentially, a similar method can be applied in the same way for sub-sub factors which are shown in table 4-7 and table 4-8:

Table 4- 6: Comparison of the relative weight of measures under strategic operations

Strategic (B_1)	Customer Service (C_1)	Financial Measurement (C_2)	Relative weight
Customer service (C_1)	1	a	—
Financial Measurement (C_2)	1/a	1	—

Source: The author

Similarly, as shown from the paired comparison of strategic matrix B_1, assume customer service factor C_1 is moderately more important than operational factor C_2, scale "a" is given. Contrarily, C_2 is moderately less important than strategic factor C_1, the reciprocal of "a", scale 1/a is given.

Table 4- 7: Comparison of relative weight of measures under customer service

Customer service (C_1)	Reliability (D_1)	Flexibility (D_2)	Relative weight
Reliability (D_1)	1	a	--
Flexibility (D_2)	1/a	1	--

Source: The author

As shown from the paired comparison matrix of customer services C_1, assume customer reliability factor D_1 is moderately more important than customer reliability D_2, scale "a" is given. Contrarily, D_2 is moderately less important than strategic factor D_1, the reciprocal of "a", scale 1/a is given.

Table 4- 8: Comparison of relative weight of measures under reliability

Reliability (D_1)	Completed order Percentage (E_1)	On-time delivery Percentage (E_2)	Customer satisfaction Percentage (E_3)	Relative weight
Completed order Percentage (E_1)	1	a	b	—
On-time delivery Percentage (E_2)	1/a	1	c	—
Customer satisfaction Percentage (E_3)	1/b	1/c	1	—

Source: The author

Also, as shown from a matrix of customer reliability D_1, assume completed order percentage E_1 is moderately more important than on-time delivery percentage E_2, scale "a" is given. Consequently, E_2 is moderately less important than E_1, thus the scale 1/a is given. Similarly scale judgments also can give on on-time delivery percentage E_2 and customer satisfaction percentage E_3.

4.5.3 Step 3: Deriving relative-importance-weight of the factors

Once the pair-wise comparison matrix has been structured, the next step is to determine the relative-importance-weight of each critical success factor, sub-factor and sub-sub-factor by pair-wise comparison.

The preference within each set of elements of the AHP hierarchy will be determined by applying Saaty's 1-9 scales, which are presented in Table 4-9 (below). A normalized matrix will be derived from these pairwise comparisons. The numerical representations for each element in the nine-point scale are derived through a combination of interview and consensual discussion with experts. Once a pairwise comparison matrix is structured for each set of elements, the weights can be obtained by solving for the eigenvector.

A nine-point intensity and definitions of the pair-wise comparison used for prioritization are given in Table 4-9:

Table 4- 9: Nine point scale for pair-wise comparison

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the object
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one over another
7	Very strong and demonstrated importance,	An activity is favored very strongly over another; its dominance of the demonstrated importance in practice
9	Extreme importance,	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8		Intermediate value, when compromise is needed
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix.

Source: Saaty (1980, 1994)

4.5.4 Step 4: Calculating the weight of critical factors

The research calculates the relative-importance-weight of the critical factors, sub-factors and sub-sub factors by using the software Yaahp. Yaahp is a free Chinese software which has been specifically derived for AHP calculation. The total contribution of critical factors to the overall performance measurement is obtained by multiplying the importance of its parent criteria and the relative importance of the criteria. The research takes an example of matrix A, and the formulation is shown as below:

$$W_i = \sum_{j=1}^{n} b_j c_{ij} \quad (i=1, 2, 3,\ldots..n)$$

Where: the matrix denoted by A, of each criterion i. where n is the total number of criteria.

4.5.5 Step 5: Computing the final performance score and rating performance

After getting the relative-importance-weight of the critical factors, subsequently the research synthesized both the relative weight of critical factors and empirical data by using software Excel. Finally the research calculates the final scores which are based on the sample automotive companies and evaluates how well each of the automotive companies' supply chain performs according to their score.

Summary

All in all, AHP application in this research for the Chinese automotive supply chain management evaluation divided into five steps: firstly the automotive industry measure framework in form of the hierarchical model. Secondly, paired comparisons of each critical factor, sub-factor and sub-sub critical factor that influence supply chain management performance measurement were built. After building paired comparisons, were calculated the relative weight of critical factor, sub-factor and sub-sub critical factor by using 1-9 scales. Finally the research multiplies relative weight and quantified empirical data and analyses automotive companies performance based on final score.

Chapter 5 AHP application and performance evaluation

This section is made up of two parts: firstly the research calculates automotive supply chain performance. In this part the research explains the backgrounds of the seven companies selected for the analysis and demonstrates application of the analytic hierarchy process. Secondly, the research evaluates each company's supply chain performance individually according to their score. In this part, each company's new technology, new managerial philosophy, and new facility utilization are also presented.

5.1 AHP application and calculation

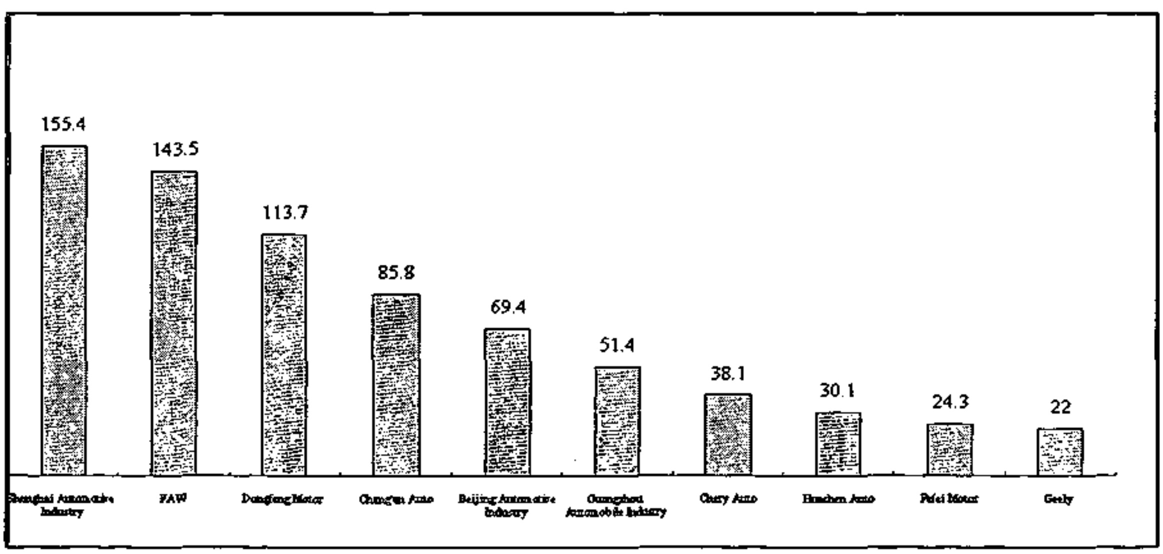
5.1.1 The selection of automotive companies for analysis

China has diversified in the automotive industry, where joint venture brands make up three quarters of the domestic car market (Lei 2006). Consistent with the purpose of this research, the research first defines Chinese automotive companies as those companies that builds manufacture and produce vehicles in the domain of China. These include foreign companies and joint venture companies.

In order to evaluate supply chain performance in the Chinese automotive industry, the top ten major automotive companies that handle the total automotive trade of the country amounting to 83.44% have been chosen (Qi and Chen 2008)(see figure 5-1).

During the data collection, three companies dropped out for various reasons. Firstly, Guangzhou Automobile Industry Holding Co. Ltd refused to provide internal data regarding the company's finance and some progressing business schedules. Secondly, Shanghai Automotive Industry Corporation bought a 20% stake of Chery in 2001, and consequently Chery Automobile Co. Ltd supply chain operation is now centrally organized by the Shanghai Automotive Industry Corporation. Thirdly, Geely Holding Group Co. Ltd entered the Hong Kong stock market. The company annual reports comply with Hong Kong stock exchange regulations, and therefore some financial data are not available for the research.

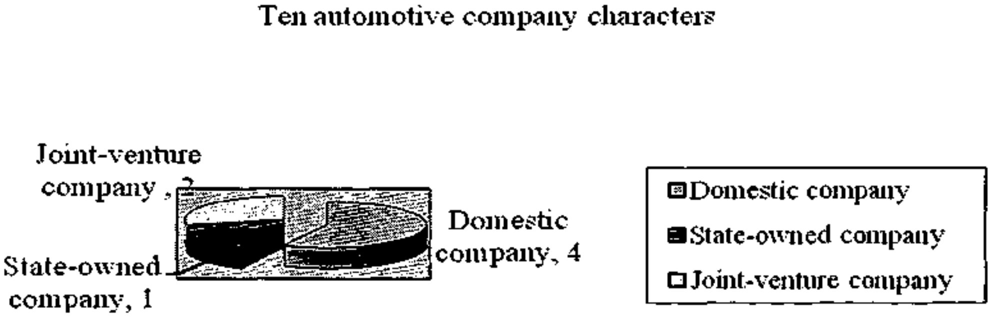
Figure 5- 1: The Top Automotive Sales in China, 2007 (Unit: 10 thousand units)



Source: Research in China (2007)

Lastly, China First Automotive Works Group (FAW) failed to provide overall supply chain operation data, and so the research had to choose the biggest completely owned subsidiary-FAW Sihuan Automotive Co from its three publicly traded subsidiaries[10], 28 divisions, 14 holding companies, and 26 joint ventures companies. In the end, seven leading companies have been chosen, which include four domestic companies, two joint-venture companies and one state owned company (see figure 5-2). These companies are: Shanghai Auto Industry Corporation (SAIC), China First Automotive Works-Sihuan (FAW), Dongfeng Motor Corporation (DFM), Chang'an Auto Co, Ltd, Beijing Automotive Industry Holding Co. Ltd, Huachen Automobile Holding Co. Ltd, and Hafei Motor Co. Ltd. The research presents seven companies, the characteristics of which are shown in table 5-1 (see appendix 6):

Figure 5- 2: Ten automotive company characters



Source: the author

[10] Three subsidiaries are FAW Sihuan Automotive, Co. Ltd, FAW Car Co. Ltd and Tianjin FAW Xiali Automobile Co. Ltd

Table 5-1: Seven sample automotive companies' profile

Company Name	Total assets[11]	Character	Employees	Car sale unit[12]	Main product / Brand name
Shanghai Automotive Industry Corporation	106.9 billion	Domestic Company	73,000	155.40	The main businesses include manufacturing and sales of passenger vehicles, commercial vehicles and vehicle parts, including power train, chassis, electronic and electric parts.
First Automotive Works (FAW)	116.7 billion	Domestic Company	129,492	143.50	The company products include economical passenger cars, medium and heavy trucks, steel wheels, and components for both FAW and other manufacturers.
Dongfeng Motor Corporation (DFM)	86.89 billion	Domestic Company	116,000	113.73	Major businesses include the manufacture of whole serial commercial vehicles, passenger vehicles, auto parts and components, as well as vehicle manufacturing equipments.
Chang'an Auto Co. Ltd	22.4 billion	Domestic Company	30,300	85.77	It operates eleven car-making factories and forms a complete model line including low-, middle- and high-class passenger and commercial vehicles.
Beijing Automotive Industry Holding Co. Ltd	42.4 billion	State-owned Company	45,000	69.41	Various vehicles including jeeps, light-duty trucks and traveling vans. Besides, the company also offers high quality agriculture machine and engineering machinery to cities nationwide.
Huachen Automobile Holding (Group) Co., Ltd.	32 billion	Joint venture Company	8,000	30.05	The company's products are minibuses, commercial and passenger vehicles and automotive components, such as gasoline engines for use in minibuses, sedans, SUV[13] and light trucks.
Hafei Motor Co., Ltd.	27.5 billion	Joint venture Company	11,000	24.31	Products ranging from single mini-automobiles to economic and middle class cars. The main automobile products include mini trucks, minivans, mini-bus, mini-cars, 3-box cars and small passenger and sedan cars.

Source: the author

[11] Currency is YUAN
[12] Unit: 10 thousand units
[13] SUV is Sports Utility Vehicles

In 2007, these seven auto companies sold 6.22 million units, taking up 70.8% of the market. In 2008, the market share for these auto companies slightly dropped, but the sales of seven automotive companies reached 6.72 million units, increasing 7.9% compared to the previous year (see table 5-2). The research lists the seven automotive companies' sales below. These are Shanghai Automotive Industry (1.72 million), Faw (1.53 million), Dongfeng (1.32 million), Chang'an (0.86 million), Beijing Auto (0.77 million), Huachen Auto (0.29 million), and Hafei Motor (0.22 million) (See table 5-2).

Table 5-2: The sales of top automotive companies (Unit: 10 thousand units)

Company name	Sales in 2007	Sales in 2008
Shanghai Automotive Industry	155.4	172
FAW	143.5	153.3
DongFeng Motor	113.7	132.1
Chang'an Auto	85.8	86.1
Beijing Auto Industry	69.4	77.2
HuaChen Auto	30.1	28.5
Hafei Motor	24.3	22.4
Total Units	622.2	671.6
Marketing share	70.8%	71.6%

Source: China Association of Automobile Manufacturers (2009)

5.1.2 Expert scale calculation

The research evaluates the performance of Chinese automotive industry supply chain management by using the analytic hierarchy process (AHP). This procedure has been approached by three steps: firstly, the experts' scale is assembled which is based on a nine-point scale and calculates the relative weight of performance measures. Secondly, the research quantifies automotive company empirical data, and finally the research synthesizes both the relative weight of measures and empirical data.

5.1.2.1 Expert scale collection procedures

After developing the performance hierarchy, a total of seven in-depth interviews were conducted to determine the relative weights of automotive supply chain performance measures. These interviewees included three researchers who were undertaking research on supply chain management or the automotive industry and four practitioners who were general managers or supply chain managers of automotive companies. During the interview, respondents were asked to make pairwise comparisons using a nine-point scale, like the one shown in table 5-3. For instance, if customer reliability is judged to be "moderately important" compared with customer flexibility according to their importance of contribution to evaluate customer service, a score of 3 is given. Conversely, if customer reliability is considered to be "moderately less important" compared with customer flexibility, a score of 1/3 is given.

Table 5-3: Nine-point measurement scale for the AHP

Degree	Verbal Judgment	Degree	Verbal Judgment
1	Equally Important	1	Equally Important
2	Between Equal and Moderate Importance	1/2	Between Equal and Moderate Less Importance
3	Moderately Important	1/3	Moderately Less Important
4	Between Moderate and Strong Importance	1/4	Between Moderate and Strong Less Importance
5	Strongly Important	1/5	Strongly Less Important
6	Between Strong and Very Strong Importance	1/6	Between Strong and Very Strong less importance
7	Very Strong Importance	1/7	Very Strong Less Importance
8	Between Very Strong and Extreme Importance	1/8	Between Very Strong and Extreme Less Importance
9	Extreme Importance	1/9	Extreme Less Importance

Source: Satty (1990)

The AHP allows the judgments of several people to be considered in the assessment process. Thus determining the relative importance of each measure is normally a collective process. In order to ensure that several managers and management accountants were involved in the AHP, three different approaches were taken:

(1) Firstly, the research carefully selected expert interviews in two rounds to measure supply chain performance in the automotive industry. During the first round, the objective of the interview was to clarify and explain supply chain performance measurement and its measures. Also, the research listed the reasons they provided for their choice and translated judgments into quantitative items.

During the second round, the research provided an anonymous summary of the experts' opinions from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other experts.

(2) After two rounds, the range of expert answers decreased and the group will converge towards the "correct" answer. Finally the research took the median scores of the final round to determine the result. The research also shows quartiles. The quartiles and median indicated that expert scales are focused and consistent. The formulation is shown below:

Assuming n number experts participating in the survey, the scale of experts on one metric can be arranged as:

$$X_1 \leq X_2 \leq \ldots\ldots \leq X_x \leq \ldots\ldots \leq X_n$$

While n is odd number, the median score can be calculated: $M = X_{\frac{n+1}{2}}$

n is even number, the median score can be calculated: $M = \dfrac{X_{n/2} + X_{(n+2)/2}}{2}$

The position of the lower quartile $j = \left[\dfrac{n+1}{4}\right]$, and the lower quartile is $Q_1 = X_j$

The position of the upper quartile $j' = \left[\dfrac{3(n+1)}{4}\right]$, and the upper quartile is $Q_3 = X_{j'}$

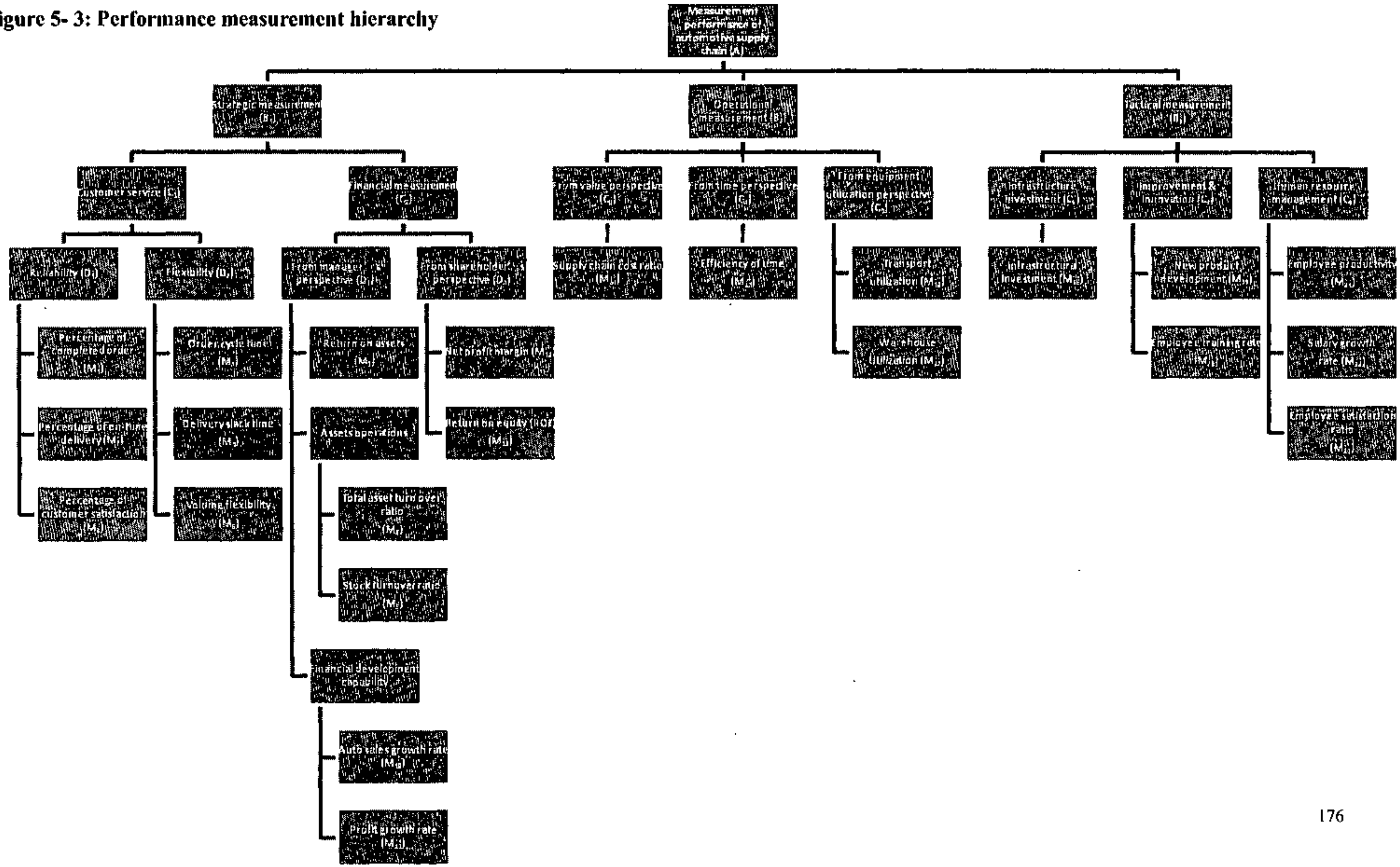
5.1.2.2 Metrics weight calculation

The research presented an approach to calculate each metric relative weight by using Yaahp software (a Chinese version of AHP software) as follows:

Step1: Building supply chain performance measurement structure

Firstly, the research sets the objective of supply chain performance measurement (A), then the research evaluates the performance from three perspectives, namely strategic performance (B_1), operational performance (B_2) and tactical performance (B_3). Furthermore three main measures are sub-divided into sub-measures. Take an example of strategic measurement. The objective of strategic management is to provide excellent service and products to customers and provide good financial return to shareholders. Therefore the research divides strategic measures into customer service measures (C_1) and financial measures (C_2). Next, the research evaluates customer service measures from a product reliability (D_1) and product flexibility (D_2) point of view. Subsequently, the same approach can be applied to other measures. The basic structure is presented below (see figure5-3):

Figure 5- 3: Performance measurement hierarchy



Step 2: Calculate each matrix based on expert scales

After building supply chain performance structure, the research collects experts' scale, the final results are shown in the table 5-4:

Table 5- 4: Expert scales and median, quartile values

Name	Seven expert scales on performance measures							Median	Lower Quartile	Upper Quartile	Range	Final result
	1	2	3	4	5	6	7					
B1:B2	5	3	5	3	3	1	3	3	3	5	2	3
B2:B3	2	3	3	2	2	3	3	3	2	3	1	3
B1:B3	6	5	7	5	5	3	5	5	5	6	1	5
C1:C2	5	3	1	2	5	1	3	3	1	5	4	3
D1:D2	1	1	3	1	2	2	2	2	1	2	1	2
D3:D4	2	3	1	2	3	2	1	2	1	3	2	2
C3:C4	1	1	1	1	2	2	2	1	1	2	1	1
C4:C5	1	3	3	3	2	2	3	3	2	3	1	3
C3:C5	1	2	3	3	3	3	3	3	2	3	1	3
C6:C7	1	1/2	2	2	1/2	2	2	2	1/2	2	2	2
C7:C8	1/5	1/5	1	1/5	1/2	1/5	1/5	1/5	1/5	1/2	3	1/5
C6:C8	1/5	1/5	3	1/3	1/5	1/3	1/3	1/3	1/5	1/3	2	1/3

Source: the author

For the matrix of measuring performance of automotive manufacturers (A), six experts considered that a strategic measurement is the most important factor which contributes to performance measurement compared with others. Customers today are not only interested in the product they are being offered but all the additional elements of service. High quality customer service helps to create customer loyalty and increase sales and profits (see table 5-5).

Table 5- 5: Performance measurement A matrix

Performance measurement A			Consistency scale: 0.0370 Weight to Goal: 1.0000	
Performance measurement A	Strategic measurement B1	Operational measurement B2	Tactical measurement B3	Relative weight Wi
Strategic measurement B1	1.0000	3.0000	5.0000	0.6370
Operational measurement B2	1/3	1.0000	3.0000	0.2583
Tactical measurement B3	0.2000	1/3	1.0000	0.1047

Source: the author

For the matrix of strategic measure (B_1), since experts came from different backgrounds, their opinions are divided into a comparison of customer service (C_1) and financial measurement (C_2). Researchers paid more attention to customer service while practitioners thought financial measurement is of the same importance as customer service (see table 5-6).

Table 5- 6: Strategic measurement B1 matrix

Strategic measurement B1			Consistency scale: 0.0000 Weight to Goal: 0.6370
Strategic measurement B1	Customer service C1	Financial measurement C2	Relative weight Wi
Customer service C1	1.0000	3.0000	0.7500
Financial measurement C2	1/3	1.0000	0.2500

Source: the author

For the matrix of customer service (C_1), experts thought product reliability (D_1) and flexibility (D_2) are equally important, however for the immature Chinese automotive industry, there are many flaws with supply chain management which need to improve, and product reliability is likely to be more important than product flexibility (see table 5-7).

Table 5- 7: Customer service C1 matrix

Customer service C1			Consistency scale: 0.0000 Weight to Goal: 0.4777
Customer service C1	**Product reliability D1**	**Product flexibility D2**	**Relative weight Wi**
Product reliability D1	**1.0000**	**2.0000**	**0.6667**
Product flexibility D2	**1/2**	**1.0000**	**0.3333**

Source: the author

For financial measurement (C_2), evaluating operation performance (D_3) is slightly more important than financial return for shareholders (D_4) (see table 5-8).

Table 5- 8: Financial measurement C2 matrix

Financial measurement C2			Consistency scale: 0.0000 Weight to Goal: 0.1592
Financial measurement C2	**From managers' perspective D3**	**From shareholder's perspective D4**	**Relative weight Wi**
From managers' perspective D3	**1.0000**	**2.0000**	**0.6667**
From shareholder's perspective D4	**1/2**	**1.0000**	**0.3333**

Source: the author

For the operational measurement matrix (B_2), experts indicated supply chain management should be based on a balance of operational cost (C_3) and lead time (C_4). Both metrics are moderately more important than equipment utilization (C_5) (see table 5-9).

Table 5- 9: Operational measurement B2 matrix

Operational measurement B2			**Consistency scale: 0.0000 Weight to Goal: 0.2583**	
Operational measurement B2	**From value perspective C3**	**From time perspective C4**	**From equipment utilization perspective C5**	**Relative weight Wi**
From value perspective C3	**1.0000**	**1.0000**	**3.0000**	**0.4286**
From time perspective C4	**1.0000**	**1.0000**	**3.0000**	**0.4286**
From equipment utilization perspective C5	**1/3**	**1/3**	**1.0000**	**0.1429**

Source: the author

For the tactical measurement matrix (B_3), human resource management (C_8) is recognized as the most valued asset in developing and executing organizational strategy. Infrastructural investment (C_6) is an essential factor for efficient supply chain operation and moderately more important than improvement and innovation (C_7) (see table 5-10).

Table 5- 10: Tactical measurement B3 matrix

Tactical measurement B3			Consistency scale: 0.0000 Weight to Goal: 0.2583	
Tactical measurement B3	**Infrastructure investment C6**	**Improvement and Innovation C7**	**Human resource management C8**	**Relative weight Wi**
Infrastructure investment C6	1.0000	2.0000	1/3	0.2297
Improvement and Innovation C7	1/2	1.0000	0.2000	0.1220
Human resource management C8	3.0000	5.0000	1.0000	0.6483

Source: the author

Step 3: Finally, the Yaahp software calculated the input data as (see table 5-11):

Table 5- 11: Final result of measures and ranking

Measures	Relative Weights
D1 Product reliability	0.3185
D2 Product flexibility	0.1592
D3 Manager' perspective	0.1062
D4 Shareholder's perspective	0.0531
C3 Value added ratio	0.1107
C4 Lead time effective	0.1107
C5 Equipment utilization rate	0.0369
C6 Infrastructural investment	0.0241
C7 Improvement and innovation	0.0128
C8 Human resource utilization	0.0679

Source: the author

5.1.3 Automotive empirical data calculation

As shown in Table 5-11, the respective weights of the ten evaluative measures are calculated by Yaahp software, listed as: product reliability (D1:0.3185), product flexibility (D2:0.1592), manager's perspective (D_3:0.1062), shareholder's perspective (D_4:0.0531), value added ratio (C_3:0.1107), lead time efficiency (C_4:0.1107), equipment utilization rate (C_5:0.0369), information system capability (C_6:0.0241), improvement and innovation (C_7:0.0128), human resource utilization (C_8:0.0679). Following, the next step is to calculate the scores of performance measurement based on the measures' relative weight and empirical data from seven automotive companies by using Excel.

5.1.3.1 Quantifying empirical data

Firstly, the research needs to quantify all uncertain companies' data into analytical measurements between 【0, 1】. The research divided the companies' data into two categories and quantified these data in two ways (Huo, Ma et al. 2002):

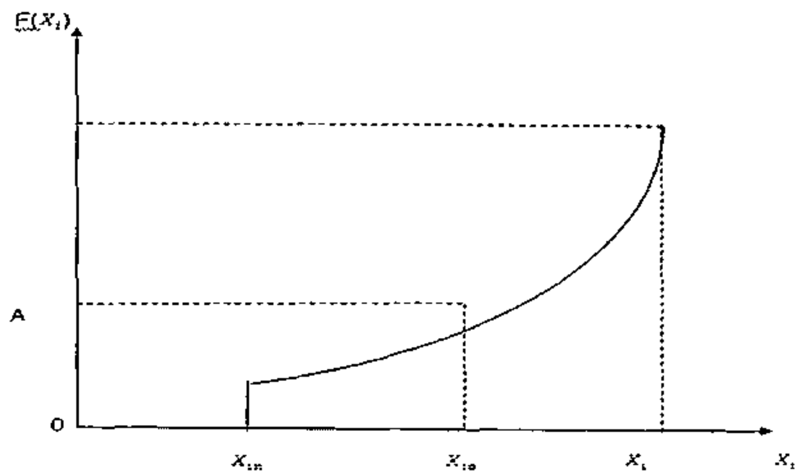
- Positive data refers to data which is as much as possible for managers, such as return on investment (ROI), auto sales growth and so on.

- Negative data refers to data which is as less as possible for managers, such as supply chain cost, customer complaints number and so on.

(1) the research quantified positive data as:

$$f(x_i)\begin{cases}1, & x_j \geq x_{i\max} \\ \dfrac{x_j - x_{i\min}}{x_{i\max} - x_{i\min}}, & x_{i\max} > x_j > x_{i\min} \\ 0, & x_j \leq x_{i\min}\end{cases}$$

Figure 5- 4: Quantifying positive data model



Source: Huo and Ma et al. (2002)

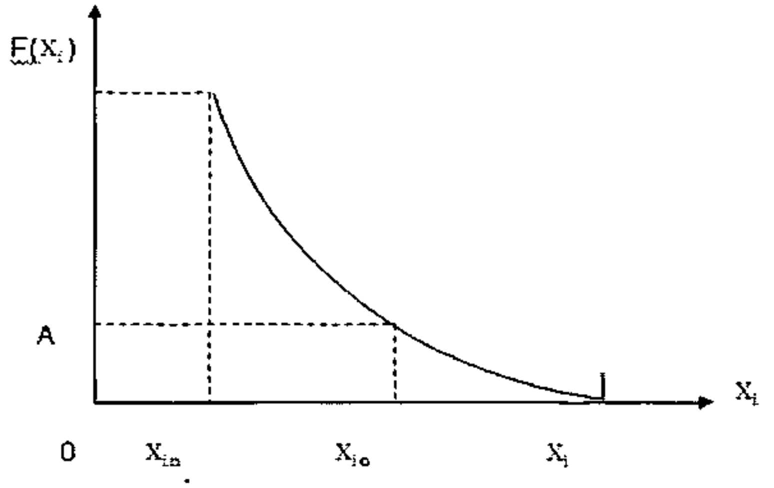
While: X_{imax} represents the maximum data for measures;

X_{imin} represents the minimum data for measures;

(2) the research quantified negative data as:

$$f(x_i)\begin{cases}0, & x_j > x_{i\max} \\ \dfrac{x_{i\max} - x_j}{x_{i\max} - x_{i\min}}, & x_{i\max} \geq x_j \geq x_{i\min} \\ 1, & x_j < x_{i\min}\end{cases}$$

Figure 5- 5: Quantifying negative data model



Source: Huo and Ma et al. (2002)

While: X_{imax} represents the maximum data for measures;

X_{imin} represents the minimum data for measures;

The research presents the original empirical data of seven automotive companies as below:

Table 5- 12: The original empirical data of seven automotive companies

Number	Type	Min	Max	C1[14]	C2[15]	C3[16]	C4[17]	C5[18]	C6[19]	C7[20]
M1	↑	50%	100%	100	100	99.3	98.3	97.5	98.1	97.7
M2	↑	50%	100%	92	93	89	84	91	87	82
M3	↑	50%	100%	94.3	95.7	93	90	90.6	91	89.7
M4	↓	3 days	30days	9.5	11	10	12.5	12	13	13.5
M5	↓	0	3	1.83	1.62	2	2.6	1.5	1.86	2.3
M6	↑	50%	100%	100	104	97	95.16	107.6	91	90.56
M7	↑	-10%	10%	5.40	2.07	3.95	3.22	4.09	-5.20	1.87
M8	↑	0	5	0.93	1.23	0.85	0.63	2.99	0.70	0.46
M9	↑	0	10%	10.12	5.87	4.58	4.68	8.05	8.30	0.85
M10	↑	0	100%	2182.7	44.24	29.63	16.06	40.53	78.01	6.29
M11	↑	0	300%	339.4	293.8	21.02	20.49	642.48	57.40	5.91
M12	↑	-10%	10%	5.84	1.69	4.62	5.08	1.37	-4.06	4.10
M13	↑	-10%	10%	10.96	3.56	7.69	6.65	16	-6.49	3.89
M14	↓	0	30%	12	10.3	13	11.2	14.4	15	13.5
M15	↑	0	1	0.44	0.4	0.5	0.31	0.4	0.33	0.29
M16	↑	50%	100%	82	75	70	73.5	80	71	67.5
M17	↑	30%	100%	85	75	71.4	73.6	81.3	81.7	68
M18	↑	0	50%	12	10	9.3	8.5	9.0	8.8	8.1
M19	↑	0	20%	19.8	16.64	17.15	15.4	14	14.43	13.07
M20	↑	0	15%	10	14.5	6.6	8.3	10	7	5
M21	↑	0	5 unit[21]	6.34	0.75	0.42	2.2	0.86	1.3	0.89
M22	↑	0	10%	7.6	8	5	7	11.3	6.5	4.8
M23	↑	50%	100%	83	81	75	78	79.6	74.7	72.5

Source: the author

[14] C1 is Shanghai Automotive Industry Cooperation
[15] C2 is Changchun Faw-Sihuan Automobile Co. Ltd
[16] C3 is Dongfeng Motor Cooperation
[17] C4 is Chang'an Auto Co. Ltd
[18] C5 is Beijing Automotive Industry Holding Co. Ltd
[19] C6 is HuaChen Automotive Holding Co. Ltd
[20] C7 is Hafei Motor Co. Ltd
[21] Unit is ten thousands YUAN

After quantifying, the data presents as (see table 5-13):

Table 5- 13: The quantifying empirical data of seven automotive companies

Metrics	C1	C2	C3	C4	C5	C6	C7
M1Percentage of completed order	1.00	1.00	0.99	0.97	0.95	0.96	0.95
M2 Percentage of on-time delivery	0.84	0.86	0.78	0.68	0.82	0.74	0.64
M3 Percentage of customer satisfaction	0.89	0.91	0.86	0.80	0.81	0.82	0.79
M4 Order cycle time	0.76	0.70	0.74	0.65	0.67	0.63	0.61
M5 Delivery slack time	0.39	0.46	0.33	0.13	0.50	0.38	0.23
M6 Volume flexibility	1.00	1.00	0.94	0.90	1.00	0.82	0.81
M7 Pre-tax return on assets (ROA)	0.77	0.61	0.70	0.66	0.71	0.24	0.60
M8 Total asset turnover ratio (ATO)	0.19	0.25	0.17	0.13	0.60	0.14	0.09
M9 Stock turnover ratio	1.00	0.59	0.46	0.47	0.81	0.83	0.09
M10 Sale growth rate	1.00	0.44	0.30	0.16	0.41	0.78	0.06
M11 Profit growth rate	1.00	0.98	0.07	0.07	1.00	0.19	0.02
M12 Net profit margin	0.79	0.59	0.73	0.76	0.57	0.30	0.71
M13 Return on equity (ROE)	1.00	0.68	0.89	0.84	1.00	0.18	0.70
M14 Supply chain cost ratio	0.60	0.66	0.57	0.63	0.52	0.50	0.55
M15 Efficiency of lead time	0.44	0.40	0.50	0.31	0.40	0.33	0.29
M16 Transport capacity utilization	0.64	0.50	0.40	0.47	0.60	0.42	0.35
M17 Warehouse capacity utilization	0.79	0.64	0.59	0.62	0.73	0.74	0.54
M18 Infrastructure investment	0.24	0.20	0.19	0.17	0.18	0.18	0.16
M19 New product development	0.99	0.84	0.86	0.77	0.70	0.72	0.66
M20 Employee training rate	0.67	0.97	0.44	0.55	0.67	0.47	0.33
M21 Employee productivity	1.00	0.15	0.08	0.44	0.17	0.26	0.18
M22 Salary growth rate	0.76	0.80	0.50	0.70	1.00	0.65	0.48
M23 Employee satisfaction ratio	0.66	0.62	0.50	0.56	0.59	0.49	0.45

Source: the author

5.1.3.2 Final overall weights calculation

Following the quantification of the automotive empirical data, the research integrated the measures of relative weight and data to calculate the final overall weights. The research takes an example of Shanghai Automotive Industry Corporation. Table 5-14 shows super matrix A, detailing the result of the relative measures importance and empirical data for automotive company supply chain performance measurement.

Table 5- 14: Supply chain performance weighted index and empirical data

					A					
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)		C2 (0.25)		C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.3185	0.1592	0.1062	0.0531	0.1107	0.1107	0.0369	0.0241	0.0128	0.0679
M1	1	0	0	0	0	0	0	0	0	0
M2	0.84	0	0	0	0	0	0	0	0	0
M3	0.89	0	0	0	0	0	0	0	0	0
M4	0	0.76	0	0	0	0	0	0	0	0
M5	0	0.39	0	0	0	0	0	0	0	0
M6	0	1	0	0	0	0	0	0	0	0
M7	0	0	0.77	0	0	0	0	0	0	0
M8	0	0	0.19	0	0	0	0	0	0	0
M9	0	0	1	0	0	0	0	0	0	0
M10	0	0	1	0	0	0	0	0	0	0
M11	0	0	1	0	0	0	0	0	0	0
M12	0	0	0	0.79	0	0	0	0	0	0
M13	0	0	0	1	0	0	0	0	0	0
M14	0	0	0	0	0.6	0	0	0	0	0
M15	0	0	0	0	0	0.44	0	0	0	0
M16	0	0	0	0	0	0	0.64	0	0	0
M17	0	0	0	0	0	0	0.79	0	0	0
M18	0	0	0	0	0	0	0	0.24	0	0
M19	0	0	0	0	0	0	0	0	0.99	0
M20	0	0	0	0	0	0	0	0	0.67	0
M21	0	0	0	0	0	0	0	0	0	1
M22	0	0	0	0	0	0	0	0	0	0.76
M23	0	0	0	0	0	0	0	0	0	0.66

Source: the author

For example, in the super matrix denoted by *A*, of each measure i. where *n* is the total number of measures. The research calculates the final overall weight of Shanghai Automotive Industry Cooperation based on the formulation as:

$$W_i = \sum_{j=1}^{n} b_j c_{ij} \quad (i=1, 2, 3, \ldots n)$$

(1) Firstly, ten measure weights were calculated by multiplying the ten measures relative weights and the quantified empirical data. The research presents examples of the calculation of weights D_1-D_4. Similarly, the same calculation can be applied for measures from C_3 to C_8:

$$W_{D1} = 0.3185 \times \begin{bmatrix} 1.00 \\ 0.84 \\ 0.89 \end{bmatrix} = 0.86950$$

$$W_{D2} = 0.1592 \times \begin{bmatrix} 0.76 \\ 0.39 \\ 1.00 \end{bmatrix} = 0.34228$$

$$W_{D3} = 0.1062 \times \begin{bmatrix} 0.77 \\ 0.19 \\ 1.00 \\ 1.00 \\ 1.00 \end{bmatrix} = 0.42055$$

$$W_{D4} = 0.0531 \times \begin{bmatrix} 0.79 \\ 1.00 \end{bmatrix} = 0.09505$$

(2) Secondly, the overall scores of Shanghai Automotive Industry Cooperation are calculated by sum of each measures final weight. The formulation is:

$$W_{Shanghai} = W_{D1} + W_{D2} + W_{D3} \cdots\cdots + W_{C7} + W_{C8}$$

Similarly, the same calculation can be applied to the other six automotive companies (see appendix 13). The final scores of the seven automotive companies' performance measurements are shown below (see table 5-15):

Table 5- 15: Final scores of seven automotive companies

Automotive Company	Final Weighting
C1 Shanghai Automotive Industry Cooperation	2.087
C2 Changchun FAW-Sihuan Automobile Co. Ltd	1.892
C3 Dongfeng Motor Cooperation	1.674
C4 Chang'an Auto Co. Ltd	1.572
C5 Beijing Automotive Industry Holding Co. Ltd	1.918
C6 HuaChen Automoitve Holding Co. Ltd	1.600
C7 Hafei Motor Co. Ltd	1.405

Source: the author

5.2 Evaluation of supply chain performance

In this section, the research evaluates the seven automotive companies' supply chain performance based on their final score and performance.

5.2.1 Ranking One: Shanghai Automotive Industry Corporation

Shanghai Automotive Industry Corporation (SAIC) takes top ranking in the supply chain performance measurement investigation. Comprehensive supply chain management accounts for its high scores. The SAIC achieved success on several performance criteria, especially: a high score on financial measurement (C2), efficient equipment utilization (C5) and high development on improvement and innovation (C7), but slightly weak on order cycle time (M4) and efficiency of lead time (M15).

In recent years, SAIC has enhanced supply chain management by:

(1) Forming a complete lean-manufacturing based system that includes every aspect of the entire supply chain such as purchasing, manufacturing, delivery, sales, after-sales and quality management (Shanghai Auto 2006).

Also SAIC has adopted lots of industry leading computer controlling technologies in manufacturing and management. Shanghai GM fully implemented the most advanced information system solution-SAP IS-AUTO. It integrated and optimized value information on manufacturing, purchasing, financing, quality control, marketing logistics, and after sales system.

(2) According to recent research, SAIC achieves 100% on completed orders, higher than all other companies. SAIC utilizes the world's leading flexible manufacturing system which allows the production of different-platform vehicles on a single production line. It covers the whole line for producing complete vehicles, including press, body, paint and general assembly, as well as the entire process for manufacturing powertrain including engines and

transmissions (Huang 2006).

(3) In terms of development on improvement and innovation, in 2007, the company released 25 new passenger vehicle models which include newly developed vehicle and redefined existing vehicle models. Table 5-16 shows the company's major subsidiaries and its brands. SAIC has one of the biggest research and development centers in China. In 2007, SAIC invested 1.92 billion yuan (around US 28.1 million dollars) to strengthen its technology centre (Bradsher 2007). Hu Maoyuan, SAIC president said "The investment will be used to develop more than 30 own brand vehicles models, these vehicles will cover a wide price range from 65,000 yuan (around US 9503 dollars) to 300,000 yuan (around US 43,860 dollars)" (Yan 2008).

Table 5- 16: SAIC major subsidiaries and vehicle brands

Major subsidiaries	Major vehicle brand
SAIC-motor	ROEWE, MG7, MG3SW, MGTF
Shanghai Volkswagen	SANTANA, SANTANA 3000, TOURAN, OCTAVIA, POLO, PASSAT
Shanghai GM	BUICK, REGAL, LACROSS, GL8, EXCELLE, SAIL, AVEO, LOVA, EPICA, SAAB, CADILLAC, PARK AVENVE
SAIC-South Korea's Ssangyong	REXTON, KYRON, ACTYON, RODIUS, NEW CHAIRMAN

Source: SAIC website (2007)

5.2.2 Ranking two: Beijing Automotive Industry Holding Co. Ltd

Beijing Automotive Industry Holding Company Ltd (Beijing Automotive) ranks second place in the performance measurement investigation. The company has advantages in financial performance, including high asset turnover (M8), profit growth (M11) and return on equity (M13). Beijing automotive also performs well on equipment utilization, including transport capacity unitization (M16) and warehouse capacity utilization (M17) and low supply chain cost (M14). But in terms of flexible delivery time (M5) and new product development (M19), the company still needs to improve. The interesting issue associated with Beijing Automotive management is that employee salary growth is higher than other companies, but employee satisfaction is lower than other companies.

In recent years, the company undertook several reforms of supply chain management. Take an example of Beijing Foton Auto, a complete subsidiary of Beijing Automotive Industry. Originally, Beijing Foton Auto had its own warehouse and transport department. In 2002, Foton Auto set up Beijing Foton Logistics Co. Ltd which is an independent third party logistics company. Foton Auto provides a physical distribution facility, such as trucks, storage trailers, pallets, and warehousing. Foton Logistics Company provided a service specialization in warehouse and delivery based on customer's requirements. After a year's trial, Foton supply chain cost has dropped 2 %, saving up to 2.7 million yuan, and the delivery time has reduced to an average of 5 days (Zhang 2006).

Also, Beijing Automotive Industry successfully implemented an advanced IT system including manufacturing execution systems (MES), enterprise resource planning (ERP) and product lifecycle management (PLM) programs. The product lifecycle management (PLM) program is a core component of Foton enterprise informatization, providing shared information between platforms to help vehicle design, manufacture, procurement, customer service and market operations (Liang 2005).

5.2.3 Rank three: FAW-Sihuan Automotive Co. Ltd

FAW-Sihuan Automotive Co. Ltd (Faw-Sihuan) shows good performance on customer service, such as 100% of customer's orders are finished (M1), 93% of orders are finished in time (M2), and 95.7% of customers are satisfied with the company's service. Also Faw-Sihuan has advantages in employee training (M20) and employees' satisfaction (M23) and salary growth (M22). The company even made an improvement in infrastructure investment, employee workplace environment and employee training support, however employee productivity (M21) is far lower than other companies and supply chain cost is the highest among all companies.

In order to increase supply chain efficiency and reduce costs, FAW-Sihuan, a complete subsidiary of First Automotive Works consolidated supply chain operations which were handled by each manufacturing plant contracting individually with logistics companies. In 2002, FAW Qiming Information Technology Co. Ltd, a wholly-owned FAW subsidiary was established. It has 405 employees and has developed a series of independent management software products. This automotive management software covers the whole automotive supply chain. The main core products include global positioning system (GPS), product data management (PDM) system, and manufacturing execution system (MES), and supply chain management (SCM) system, office automation (OA), sales management system (TDS) and so on. These software have been successfully applied to 14 manufacturing plants and 3000 auto parts suppliers, vehicle distributors and retailers (Xie 2007).

FAW has also exploited the capability of new product development and IT technology. It manages the largest and most extensive research and development centre in China, with a 40 year history, currently employing over 1,800 people with a capital investment of 2 billion yuan (around 29.24 million US$), designing vehicle, chassis, drivetrain and other components. The centre is also a government authorized testing center for development, modification, evaluation, and testing of future vehicles (FAW New 2008).

5.2.4 Rank four: Dongfeng Motor Cooperation

Dongfeng Motor Cooperation, shortened to Dongfeng, has good performance on completed customers' order (M1) and new product development (M19), however in terms of human resource management (M21, M22 and M23), supply chain efficiency (M4), and equipment utilization (M16 and M17), the company still needs to improve. In recent years, Dongfeng, has sought methods to improve low supply chain efficiency, reduce vehicle cycle time and improve equipment utilization (Guo and Qing 2005):

(1) Flexible transport modes application

Dongfeng combined railroad and trucking transport delivery to reduce supply chain cost and delivery time. The company selects railway delivery for large materials[22] and vehicles. This takes longer but can save cost. For small and medium-sized materials and parts delivery, the company selects trucking transport because it is flexible and faster. Significant savings in vehicle manufacturing time have been achieved and for Dongfeng, the average cycle time for a passenger vehicle is now only ten working days, 2nd only behind SAIC.

(2) Transport utilization improvement

Dongfeng also redesigned the transport facility to improve equipment utilization. Take an example of 4-ton transport trucks, Dongfeng used to select 4-ton transport trucks which can carry two vehicles and the transport

[22] Large materials include body, chassis, axle, wheels, engine, gearbox and so on.

utilization was 25 %. Now Dongfeng has changed to 3-ton light-duty trucks and extended the trucks' floor, and the new model trucks can be fitted for 3 unit vehicles reducing loaded waste and petrol cost. Transport utilization has grown to 50 %. Moreover Dongfeng arranged two-way delivery between different manufacturing plants, resulting in better utilization of transport and reduced empty-loaded delivery (Sheng and Zhong 2008).

(3) Modern procurement system application

Dongfeng built an integrated procurement system instead of its manual procurement processes. The new procurement system allows suppliers to check forthcoming orders and payments, and also provides timely information regarding vehicle parts purchase and delivery to manufacturers. It helps to reduce administration costs and speed up vehicle order cycle time (Gua and Hao 2007).

5.2.5 Rank five: Huachen Automobile Holding Co. Ltd

In 2007, Huachen Automobile Holding Co. Ltd (Huachen) sales grew 78.01%, ranking in the top two, just behind SAIC. The company's four main models: BMW-Brilliance series, Junjie sedan, Zunchi sedans and Kubao coupe contributed to high growth on vehicle sales (M10). As the company experienced unprecedented development on the automotive market, the issues of supply chain management emerged. The main problems are related to financial management. In 2007, HuaChen's return on assets (M7) is -5.2%, and Net profit margin (M12) and Return on equity (M13) is -4.06% and -6.49% respectively. Also supply chain cost (M14) is much higher than other automotive companies, and represented 15% of company sales.

Huachen has improved its supply chain performance through the three following approaches (Ma and Wei 2006):

(1) Enhanced co-operation with suppliers

Huachen enhanced its co-operation with suppliers to reduce the material cost and manufacturing lead time. BMW-Brilliance, a joint venture between BMW and Huachen, set out the most important steps to localize its production in China. At the beginning of 2006, when BMW Brilliance imported parts from the BMW group, the number of local suppliers was only 46, and procurement cost was two billion yuan. In 2007, more and more local suppliers took part in the BMW Brilliance's supply chain team. BMW Brilliance suppliers reached more than 100, and local purchases grew to 3.6 billion (Company's Website News 2007).

(2) Improve production capacity

In order to increase market share and satisfy customer demand, Huachen planned to increase production capacity. In 2006, BMW Brilliance had production lines that have the capability of manufacturing 30,000 units a year, however the sales of BMW series 3 and series 5 cars reached more than 40,000 units, thus Huachen set up a second manufacturing plant. After the completion of the new plant, production capacity can reach 50,000 units a year, increasing by 66% (Xu, Jing et al. 2007).

(3) Improve IT system application

Huachen encourages its subsidiaries to implement an IT system and use computer networks for efficient management of the production and supply chain. At present, Huachen Jinbei, one of Huachen's subsidiaries, has been implementing intranet information systems for its production, finance, and human resources management. At the same time, Huachen keeps on updating its information system to meet customer needs. These systems include dealer management system (DMS), customer relationship management (CRM) systems and others.

5.2.6 Rank six: Chang'an Auto Co. Ltd

According to the research, Chang'an (Chang'an Auto Co. Ltd) has strengths on net profit margin (M12) and employee productivity (M21). Comparatively Chang'an has weaknesses on several aspects: from the customer service perspective, Chang'an on-time delivery (M2) and customer satisfaction (M3) still need to improve. From the financial perspective, Chang'an asset turnover ratio (M8), sales growth rate (M10) and profit growth rate (M11) is low. Also Chang'an has issues on supply chain cost (M14), efficiency of lead time (M15) and infrastructure investment (M18). In the future, Chang'an should increase infrastructure investment to improve supply chain efficiency and reduce the product cycle time to satisfy customers.

Chang'an realized the company needed to adopt a modern enterprise resource planning (ERP) package. In 2000, the company implemented several Oracle E-Business Suite modules which included an enterprise resource planning (ERP) system. The packaging integrates 38 disparate sub-systems and operations covering manufacturing, inventory and procurement. A centralized supply chain management not only lowers administration costs, but also improves information sharing, data accuracy and operational efficiency (Oracle Consulting 2008).

In 2003, Chang'an upgraded the ERP system for automating operations, such as accounting, manufacturing, and logistics. The ERP system streamlined the supply chain and promoted better communication with suppliers. The company's net profit increased 173% in the 2006 fiscal year (Chang'an Auto website 2007).

Also the implementation of inventory software has enabled Chang'an to efficiently manage inventory, reduce equipment utilization waste and increase material usage. The company cut inventory cost from 120 million yuan to 83 million yuan, and no longer needed to maintain a 80,000-square meter warehouse to store products (Oracle Consulting 2008).

5.2.7 Rank seven: Hafei Motor Co. Ltd

Hafei has good performance on product cycle time (M4), delivery slack time (M5) and net profit margin (M12), but in the future, Hafei supply chain management needs to improve a number of areas in terms of financial measurement. Hafei has extremely low asset turnover ratio (M8), stock turnover ratio (M9), and sales growth rate (M10) and profit growth rate (M11). Equipment utilization, transport capacity utilization (M16) and warehouse capacity utilization (M17) also need to improve. In terms of human resource management, Hafei should provide better welfare for employees (M22, M23) and encourage and support employee training programmes (M20).

Shi-feng Guan, a deputy chief of the operation strategy department, said “Hafei is one of the earliest companies who implemented an information system, an excellent information system provides a good platform for communication between different participants". In 2006, Hafei built an enterprise web *information system,* covering 100 retailers and 1000 repair sites in China. After a one year trial, Hafei procurement and inventory costs were reduced by 11 %, the cycle time for procurement and manufacturing reduced by 25 % and the average cost for each vehicle reduced by 1020 yuan (Zhou, Deng et al. 2006).

Moreover, Hafei seeks strategic advantages by using third party logistics. The service included two parts, one part is inbound material flow management, inventory control, container and packaging management. The other part is providing vehicle just-in-time delivery to reduce the delivery time and improve customer service. Also the third logistics party service helps Hafei to better control supply chain operations, reducing operational costs and improving product quality (Huang and Lin 2005).

5.2.8 Conclusion

After analysis of seven automotive companies' performance separately, the characteristics of automotive companies supply chain management can be summarized as:

1) Automotive companies focus on supply chain software development which mentioned in the previous section, such as leading computer technology implementation, supply chain management software and advanced manufacturing systems application. However automotive companies failed to support human resource management, such as employee education. According to the investigation, it shows that employee training courses are more focused on market strategy or

vehicle design rather than supply chain operation education. Also the average employee satisfaction is only 77.69%. The problems include: employee's feel stressful, work environment need to improve, and communication between managers and employees needs to be enhanced. Thus automotive companies still need to do more on several aspects.

2) High growth in the automotive industry development continues and automotive company sales retain high growth. The research found almost all automotive companies still face financial problems. Some companies have problems in asset operation and investment return for shareholders, and some companies have problems in terms of profit margin and supply chain cost. Take an example of Beijing automotive company. In 2007, Beijing automotive company profit growth is 642.48%, ranking number one in seven companies, but the company's net profit margin is only 1.37%, far behind the other six companies. The same situation is faced by Hua Chen automotive company. In 2007, sale growth of Hua Chen is 78.1%, ranking number one in seven companies, however Hua Chen return on asset is -5.2%, and shareholders cannot receive profit from their investment.

3) Finally companies face problems of enhancing efficient supply chain management. The study showed that the average efficiency of lead time is only 0.38, which means the actual vehicle delivery time is twice the ideal, and too much time in wasted on zero-value activity. Also equipment utilization is relatively low. The

lowest transport capacity utilization and warehouse capacity utilization is only 67.5% and 68% separately in Hafei Automotive company. Thus in the future, automotive companies should emphasize supply chain efficiency improvement and maximum equipment utilization.

Chapter 6 Analysis of supply chain performance

The previous chapter demonstrated AHP application in performance measurement and evaluated seven automotive companies' supply chain performance individually. In this chapter, the research will further evaluate the automotive industry based on seven sample companies from four perspectives: customer's perspective, financial perspective, infrastructural perspective and human resource management perspective. In terms of a customer perspective, the research analyses from a customer satisfaction area and dissatisfaction area; In terms of a financial perspective, the research points out two characteristics of automotive companies: high growth on sales and profit but low profit and assets return; In terms of an infrastructure perspective, the research presents two issues: inefficient equipment utilization and shortage of investment on infrastructure; And in terms of a human resource management perspective, the research assesses from employee satisfaction ratio and training utilization rate.

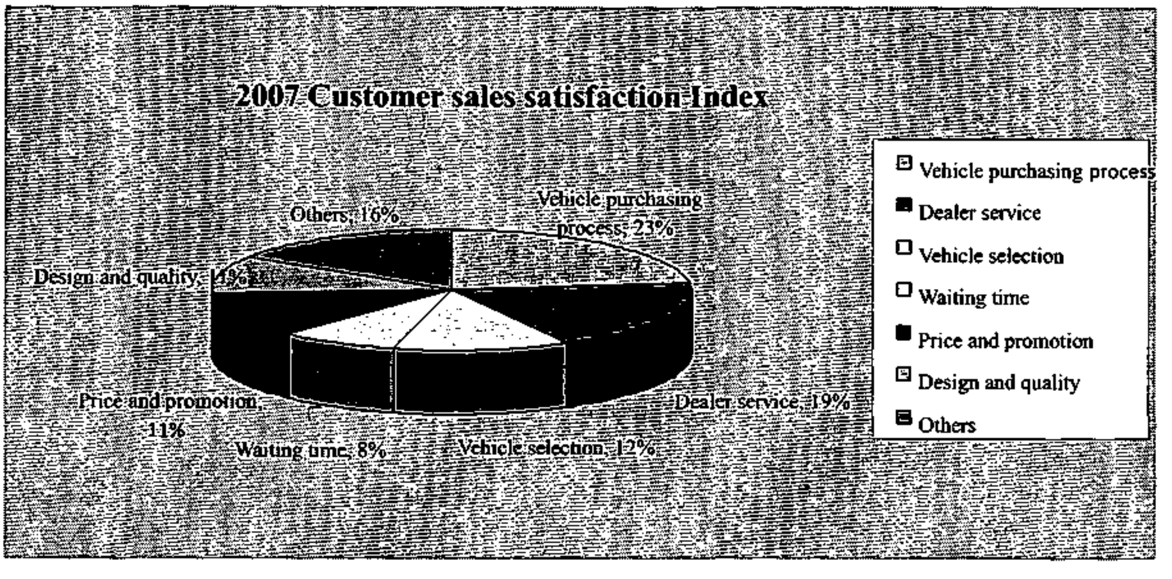
6.1 Analysis from a customer perspective

In this part, the research attempts to analyze automotive supply chain performance from both sides: customer satisfaction and customer dissatisfaction.

6.1.1 Customer satisfaction

According to J.D. Power and Chinese Automotive Associates 2007 Sales Satisfaction Index (SSI) Study, the overall satisfaction in the automotive industry is 764 points, up 27 points compared with the previous year. The 2007 SSI study is based on responses from more than 17, 396 new vehicle owners covering 48 vehicle brands in 26 cities. The research measures overall customer satisfaction by examining seven factors (listed in order of importance): vehicle purchasing process, dealer service, vehicle selection, sale price and promotion, design and quality and waiting time.

Figure 6- 1: 2007 Customer satisfaction index study

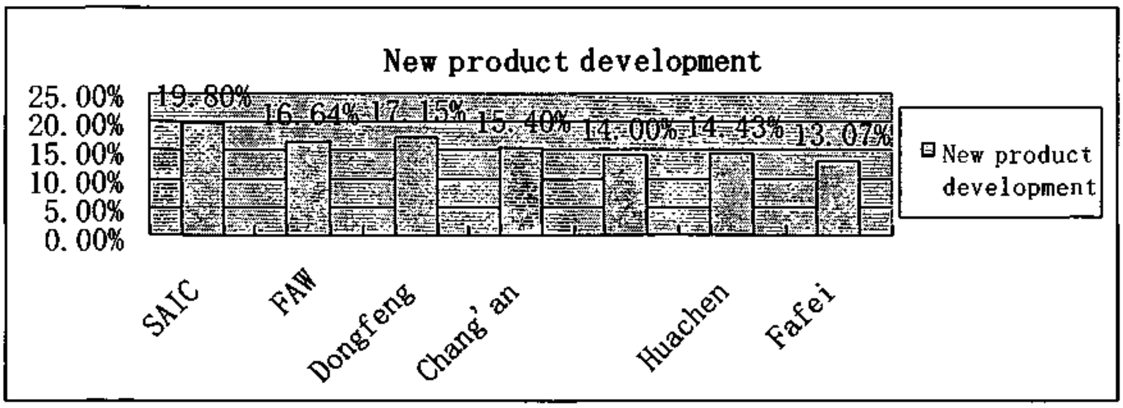


Source: Tews (2008)

As shown from the customer satisfaction index study (see Figure 6-1), vehicle purchasing process, dealer service and vehicle selection achieved high customer satisfaction. Shanghai Automotive Industry Corporation (SAIC) ranks the top, receiving a score of 831 out of a potential 1,000. Following SAIC in rank are First Automotive Works (FAW) (823) and Guangzhou Automotive Industry Group (819) (2008). A lot of automotive companies focused on what customers want and attempt to improve in areas which affect customer satisfaction, such as in the area of service quality and vehicle price (Tews 2008).

According to the research investigation, the average customer satisfaction ratio is 92%. Most customers are satisfied with new product development, vehicle price and promotion and vehicle design. The research investigation showed that for the new product development ratio, Shanghai Automotive Corporation, First Automotive Works and Dongfeng Company ranked the top three out of seven automotive companies. The average of these seven companies' new vehicle models ratio is 15.78% which means new products took up more than 15% of total vehicle models (see figure 6-2).

Figure 6- 2: Automotive companies' new product development ratio



Source: the author

Beijing Automotive Research showed that, in 2006, there were more than 334 new vehicle models available in China, including more than 117 new passenger vehicle models. Customers are satisfied with more options for vehicle models. In 2007, more than 80 new passenger vehicle models were placed in the market which means that automotive companies established a new vehicle model every four days. Completed new vehicle models were 48, accounting for 60 % of the total new vehicle models in China (Nu and Zhang 2006; Zhu and Wang 2008).

Take the example of DongFeng Motor Group. The research found that in 2007 Dongfeng Motor produced 40 new commercial vehicles models, including 32 new truck models and 8 new bus models (Dongfeng Annual Results Announcement 2008). Dongfeng Nissan, one of Dongfeng Motor Group's passenger vehicle manufacturers, achieved annual sales of more than 450,000 units and introduced eight new vehicle models to China, and Dongfeng Peugeot also grew its sales 14.5 % by relying on three new vehicle models (Yan 2009).

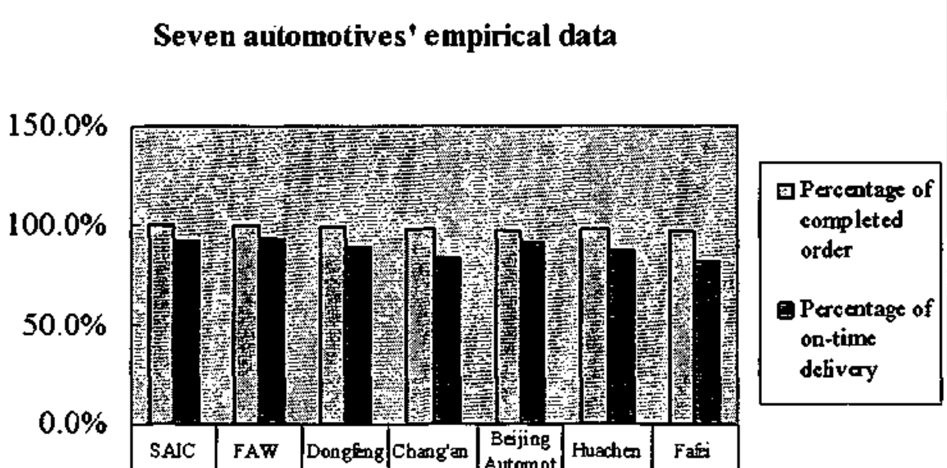
6.1.2 Customer dissatisfaction

From a customer dissatisfaction perspective, the research found most customers are dissatisfied with new vehicles which are out of stock and require a long customer waiting time.

6.1.2.1 Out of stock

The research investigation showed the average percentage of completed orders for the automotive industry is 98.7% and the percentage of on-time delivery for customers is 88.3% (see figure 6-3). Out of stock in the market is an issue for automotive companies. The research considered reasons for out of stock are: firstly, the major automotive companies are joint ventures and most automotive parts are exported from other countries and so it takes long time to procure auto parts and transfer them to China. Otherwise many new models, especially those in high demand but limited supply, have too many orders which cannot be fulfilled in time. Chen Lei, an Chery Auto's senior salesman said: "the cheapest Chery auto is only 30,000 yuan (US 4386 dollars), now the Chinese new year is coming, at least 10 vehicles are sold in our shop every day, 80 % of which are bought by individual buyers. Many products are out of stock, so buyers have to wait for months."

Figure 6- 3: The percentage of completed order and on-time delivery



	SAIC	FAW	Dongfeng	Chang'an	Beijing Automot	Huachen	Fafei
Percentage of completed order	100.0%	100.0%	99.3%	98.3%	97.5%	98.1%	97.7%
Percentage of on-time delivery	92.0%	93.0%	89.0%	84.0%	91.0%	87.0%	82.0%

Source: the author

The research suggested that in order to prevent the product from becoming out of stock, the automotive manufacturers should enhance integration with partners, sharing vehicle demand information seamlessly across the supply chain. Furthermore, the research advocated Zhou and Xue et al.' s advice (2007) that the automotive companies should develop a pre-caution system, whereby both the vehicle orders and inventory items are transferred automatically. For example, a vehicle which a customer requires is found to be out of stock in one of the dealer's inventory. After an inquiry, if companies find the vehicle is situated within another inventory which belongs to the same company, in this case, stock could be repositioned to where the demand exists.

6.1.2.2 Long waiting time

The research investigation showed another area for customer dissatisfaction is the long waiting time to obtain a vehicle. Automotive companies should consider the customers' waiting time for fulfillment of a requested order. According to the online survey based on 100 respondents, 72 customers were willing to wait two weeks for a new vehicle and only 15 customers will wait up to eight weeks (Zhao and Xiong 2008). The research investigation showed the average cycle time is 11.6 working days from receiving customer orders to final vehicle delivery, and during a promotion or the Chinese traditional festival, customers have to wait longer (see table 6-1).

Table 6- 1: Seven automotive companies' delivery time and order cycle time

	SAIC	FAW	Dong feng	Chang' an	Beijing Automotive	Hua chen	Fafei
The longest delivery time	7.5 days	9 days	7 days	9 days	8 days	9.5 days	10 days
The shortest delivery time	2 days	2.5 days	1 days	2.5 days	3.5 days	3 days	3 days
Order cycle time	9.5 days	11 days	10 days	12.5 days	12 days	13 days	13.5 days

Source: the author

In Japan, the average vehicle production time is 28.5 hours, with 56 hours for a BMW 7-Series and 35.8 hours for a Ford. However in China, vehicle manufacture needs four to five days (unit: eight hours a day) and delivery time is five to seven days. Tang and Qiana (2007) traced reasons as there is often a disconnection between departments and software systems among suppliers and retailers along with the supply chain. This wastes time used in processing, product planning, manufacturing and delivery. Today, automotive companies such as Shanghai Automotive Industry Cooperation and Huachen Automotive are looking to product lifecycle management (PLM) solutions to reduce time to the market. PLM is not only driving forward product innovation to attract new customers, but it is also transferring product information from its initial concept through to design, launch, production and final delivery—with internal and external partners to the automotive companies (Yang and Chen 2008). It speeds up order cycle times and integrates information between departments to synchronize critical product data throughout the product lifecycle.

6.2 Analysis from a financial perspective

In this part, the research represents characteristics of the Chinese automotive industry from a financial perspective: high growth on sales and profit, low profit and assets return.

6.2.1 High growth on sales and profit

In 2007, China's automotive industry has maintained fast growth, and sedan cars accounted for an increased percentage. In the Chinese market, the total vehicle trade reached 1017.61 billion yuan (around US148.77 billion dollars). Compared to the previous year, vehicle sales are increasing 209.11 billion yuan (around US 30.57 billion dollars), growing by 25.86 % (Center for Information Industry Development (CCID) 2008).

The research investigation revealed that more than 100 companies, Shanghai Automotive Industry Corporation had an outstanding performance in China. As mentioned in the previous section, Shanghai Automotive's joint ventures with General Motors and Shanghai Volkswagen Automotive Company make various passenger cars, such as Buick and Santana. Also Shanghai Automotive signed a cooperation agreement with Nanjing Automobile Corporation (NAC), developing new vehicle models, including MG 7 and ROEWE 750 (Bi 2007). In 2007, the automotive company recorded the highest growth in China at 155.4 units, and profit growth of 339.39% (See table 6-2).

Table 6- 2: Seven automotive companies' financial data

Year 2007	M8	M9	M10	M11	M12	M13	M14
Full name	return on assets (ROA)	Total asset turnover ratio	Inventory turnover ratio	Sale growth rate	Profit growth rate	Net profit margin	Return on equity (ROE)
SAIC[23]	5.40%	0.93%	10.12	2182.68%	339.39%	5.84%	10.96%
FAW-Sihuan	2.07%	1.23%	5.87	44.24%	293.83%	1.69%	3.56%
Dong feng	3.95%	0.85%	4.58	29.63%	21.02%	4.62%	7.69%
Chang'an	3.22%	0.63%	4.68	16.06%	20.49%	5.08%	6.65%
Beijing Automotive	4.09%	2.99%	8.05	40.53%	642.48%	1.37%	16.00%
Hua Chen	-5.20%	0.70%	8.30	78.10%	57.40%	-4.06%	-6.49%
Ha fei	1.87%	0.46%	0.85	6.29%	5.91%	4.10%	3.89%
Average	2.20%	1.11%	6.06	342.50%	197.22%	2.66%	6.04%

Source: derived from company reports by the author

In addition to Shanghai Automotive, Beijing Automotive[24] also has achieved high value growth in vehicle sales and profit. The average sales and profit growth for the seven automotive companies are 342.50 % and 197.22 % respectively. Generally, the automotive industry keeps growing strongly, except the Huachen Automobile Companies. In 2007 Huachen Automobile lost approximately 0. 229 billion yuan during the first three quarters, and profit has fallen from 20.8 % to 11.1 %. Mr. Lei Shi, as a director and chief financial officer of Huachen Automobile Component Co., Ltd., said several factors contributed to the profit and equity loss, losing market share,

[23] Short name for "Shanghai Automotive Industry Corporation"

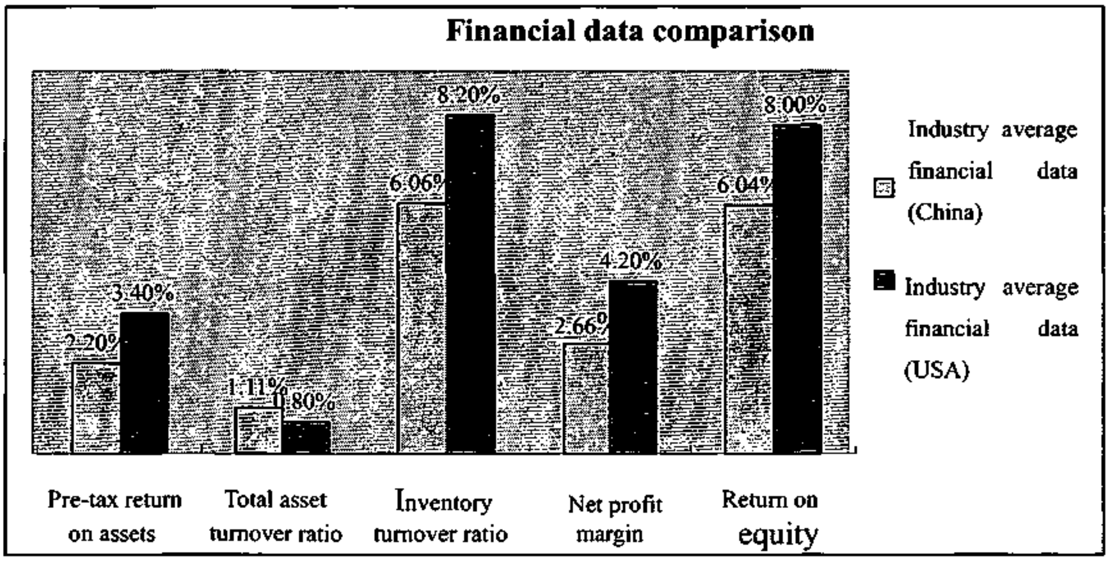
[24] Short name for "Beijing Automotive Industry Holding Co. Ltd"

vehicle price slumping and increasing material costs. In the future, Huachen plan to introduce Chinese-built 3 and 5 series BMW sedans and strengthen their cooperation with supply chain participants to reduce material procurement and vehicle manufacturing costs (Qian and Meng 2007).

6.2.2 Low profit and assets return

The empirical data showed that automotive companies have strong performance in terms of sales and profit growth. However net profit margins are relatively low. The average return on assets is only 2.20 % for Chinese automotive companies and the net profit margin is 2.66 % compared with 4.20 % for the American automotive industry (see figure 6-4) (Wang and Ma 2008). The research believed high transport cost and inefficient inventory management are main factors for the low financial return.

Figure 6- 4: Financial data comparison between China and the USA



Source: Wang and Ma (2008)

6.2.2.1 High transport cost

The research revealed that factors causing high transport cost are: in China, transport infrastructure is underdeveloped in some developing cities. Most manufacturing material and vehicles are delivered by truck for short distances. As petrol costs and highway taxes are increasing, this transport mode not only suffers in delaying vehicle delivery time, but also increases transport costs. Moreover, Liu and Qiu et al.(2007) described in order to deliver vehicles over long distances, automotive companies have to use a combined transportation mode. According to research undertaken at Northern Jiaotong University, a new vehicle has to be loaded and uploaded more than ten times during each delivery on average. Different transport and packaging causes lower vehicle transport efficiency and adds extra operational cost.

Moreover, the research thought that Chinese automotive companies failed to provide real-time information to participants, such as truck drivers, suppliers and retailers. Take an example of a delivery truck that has the capability of carrying 12 vehicles each time, the major delivery trucks actually achieve only 68% - 73% of potential capacity on average. The main reason for delivery trucks failing to maximize their capability is that automotive companies cannot access information quickly and consequently organize the task more efficiently. Thus the research proposes that Chinese automotive manufacturers should develop an automatic vehicle tracking system (AVTS) widely to monitor vehicle shipments which allows vehicles to be tracked and data collected in real time, such as track location, product volume etc. This will help managers to schedule the delivery in advance and increase the efficiency of delivery operation and inventory management.

6.2.2.2 Inefficient inventory management

With inevitable uncertainty of demand and lead time requirements, inventory acts as a buffer between supply and demand fluctuations. As a result, maintaining the appropriate levels and types of inventory is essential to provide quality and timely service to customers. However overstocking products take up the companies' capital and reduces asset return and profit growth. According to Guodu Securities Research Centre, in 2007, the total inventory value of the Chinese automotive industry was 43.70 billion yuan and 23.72 % companies' assets are tied up in inventory (Jing and Waller 2008). The research investigation showed the inventory turnover for Chinese automotive companies is 6.06 which means that every 59.4 days the inventory turns over once while the figure is only 43.9 days for the American automotive industry.

Jiejing Jiang, as a supply chain project manager of FAW, said that the Chinese automotive companies should reduce inventory value and improve capital efficiency through better inventory management, Ding and Cui et al. (2006) advise Chinese automotive companies may optimize inventories through:

- Developing just-in-time delivery system to improve information reliability and reduce forecasting variability.

- Build a regional distribution center (RDC) to reduce the inventory and respond more efficiently to the retailers and customers' orders.

Shark (2008) described an example of BMW's new distribution system, which focuses on a new BMW Regional Distribution Center (RDC) established in the province of Guangzhou since 2008. The centre keeps at least 387 vehicles for safety stock and supplies vehicles to 25 linked retailers in South China. With the operation of three Regional Distribution Centers in Beijing, Shanghai and Guangzhou, BMW can now offer quick vehicle delivery service for all retailers to cover the Chinese mainland. For urgent customer requirements, vehicles can be delivered automatically out of one of three regional distribution centers to all retailers in China over-night.

6.3 From an infrastructure perspective

This section will consider two characteristics of supply chain infrastructure performance: inefficient equipment utilization and low infrastructure investment.

6.3.1 Inefficient equipment utilization

In recent years Chinese automotive companies have seen a rapid expansion, and by

2007, the Chinese automotive production capacity was more than 10 million units. Recently Shanghai Passenger Car Company [25] launched its 150,000-unit-a-year production facility, where its self-developed sedan Roewe 550, Roewe 750 and some MG vehicle models are expected to be made. With its manufacturing plants being built in Yizheng and Pukou, Shanghai Passenger Car Company will boost its production capacity to 400,000 units. However the Roewe sales in 2007 were only 17,000 units and sales of MG-7 car models were less than 5,000 units, both falling short of the sales expectation (China Car Times 2008). Sichuan FAW Toyota, one of the joint ventures between FAW Group Corporation and Toyota Motor Corporation, introduced a 100,000 unit-a-year production facility in 2006. The expansion will boost the production capacity of Toyota and FAW's joint venture to 570,000 units. In contrast, the venture only sold a total of 282,600 vehicles in 2007. Chinese manufacturer Haima Investment Group Cooperative also built two plants to triple its annual car production capacity to 450,000 units, however in 2007 the domestic manufacturer only sold 130,000 cars (China Automotive News 2008).

As shown in table 6-3, in 2007, companies' sales are far less than production capacity. In 2008, only FAW Car Cooperative, Shanghai Passenger Car and Guangzhou Toyota had sales more than their production capacity. Signs of overcapacity in China's automotive industry have become apparent.

[25] Shanghai passenger car is one of Shanghai automotive industry corporation (SAIC) subsidiary companies.

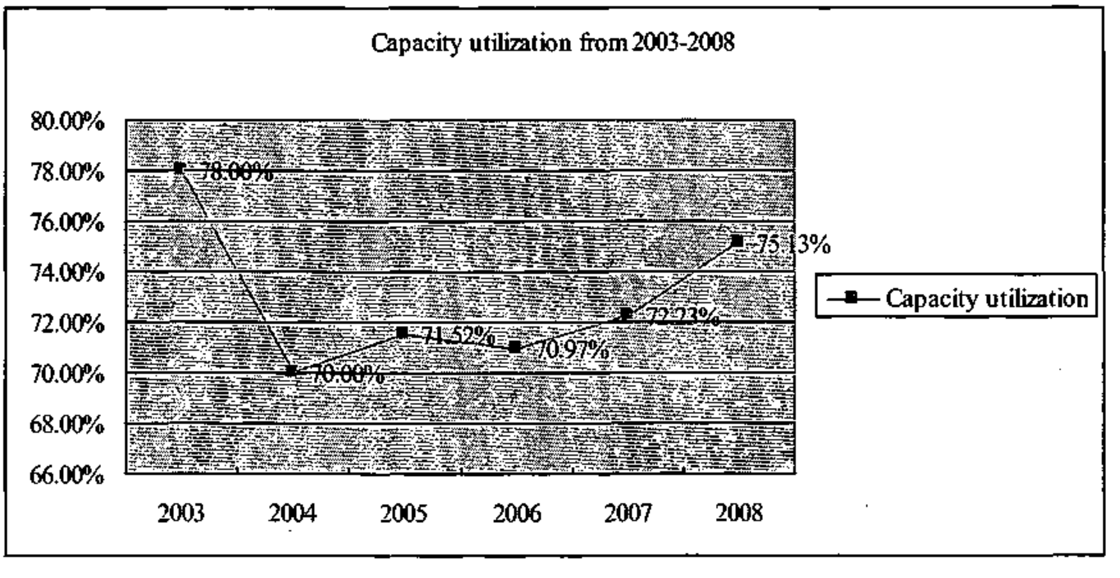
Table 6- 3: Automotive companies' production capability and sales

Automaker	Production capacity (Units)	Sales, 2007 (Units)	Sales, 2008 (Units)
FAW Car Co	200,000	8,000	298,953
Shanghai passenger car	300,000	25,000	444,756
Chery	650,000	381,000	356,093
Geely	530,000	181,500	221,800
Haima Auto	450,000	130,000	100,000
FAW Toyota	570,000	282,600	366,045
Guangzhou Toyota	200,000	170,000	306,230
Beijing Hyundai	500,000	260,000	294,506
Dongfeng Nissan	450,000	271,900	350,520

Source: Company press release (2009)

From 2003 to 2008 the average capacity utilization ratio is 73.83% (see figure 6-5). In 2007, Chinese automotive capacity utilization ratio was 72.23% while Japan was 97.5 %, Germany was 84.5%, and USA was 78.60%. The Chinese passenger vehicle production capacity even reached bottom at 55 % (Wu and Chu 2009).

Figure 6- 5: 2003-2008 capacity utilization in the automotive industry



Source: Wu and Chu (2009)

Kwan (2005) indicated that reasons for investment growth in Chinese automotive production capability include high demand from the automotive market, and foreign automakers expanding into China. Low production capability utilization also causes supply chain equipment unitization to drop. According to the investigation, the research found the average of vehicle transport capacity utilization is 74.1% and the average of warehouse capacity utilization is 76.5 % (see table 6-4). Along with low equipment utilization, manufacturing cost and supply chain cost are accumulated. In order to eliminate waste, the research follows Jiang and Wu (2006) and Zhu and Jiang's (2007) recommendations for automotive companies:

- Improving sale forecasting accuracy and system flexibility, and building a supply chain management system based on vehicle demand scheduling.

- Enhance mutual collaboration with suppliers and retailers. Improving exchange information quantity and quality, this will help to reduce the product cycle time and provide better service to the final customers.

Table 6- 4: Transport capacity utilization and warehouse capacity utilization

	AIC	FAW	Dongfeng	Chang'an	Beijing Automotive	Huachen	Fafei	Average
Transport capacity utilization	82.0%	75.0%	70.0%	73.5%	80.0%	71.0%	67.5%	74.1%
Warehouse capacity utilization	85.0%	75.0%	71.4%	73.6%	81.3%	81.7%	68.0%	76.6%

Source: The author

6.3.2 Shortage of investment on infrastructure

In recent years, due to high demand for vehicles, automotive companies have expanded investment on production equipment. However investment on supply chain equipment only takes up 9.38 % of vehicle profits and this lags behind other developed counties (Zhong and Xie 2008). Thus the research suggests that in the future, automotive companies should increase investment on supply chain infrastructure in terms of both hardware and software.

6.3.2.1 Hardware investment

Automotive companies should increase investment to upgrade logistics equipment and technology from these aspects:

1) During the investigation, the research observed some small automotive manufacturers still use outdated equipment, and this equipment represents low efficiency and low security. Thus the research suggests that manufacturers should develop advanced logistics equipment, such as using professional storage equipment, building automated storage systems and setting up automatic sorting and monitoring equipment. It will not only help to save shipping and storage costs, but also can reduce manufacturing setup time. Take an example of the professional delivery truck. For Chinese automotive manufacturers, the container is the safest package for vehicle delivery, especially for long distance transport, however, due

to various truck sizes, new vehicles have to be packaged and re-packaged several times, causing product damage and delaying delivery time.

2) Secondly, the research proposes information based identification and control equipment should be widely applied by automotive manufacturers; these include bar codes, electronic data interchange (EDI), radio frequency (RF) tag, GPS (global positioning system) and so on. Take an example of GPS. After setting up GPS, manufacturers can store, exchange, and process in-time delivery information. The information includes customer order data, route arrangement, road traffic and truck position, and it helps staff to be ready before the delivery truck arrives. Also the research encourages manufacturers sharing information with suppliers and retailers to help making better arrangements and reducing vehicle cycle time.

6.3.2.2 Software investment

Li and Lin (2008) claimed the development of automotive IT application in the Chinese automotive industry has gone through three stages:

1) From 1980-1992, IT applications used research and development for automotive design, such as CAD[26], CAM[27] and CAE[28].

---

[26] CAD is computer aided design.
[27] CAM is computer aided manufacturing
[28] CAE is computer aided engineering

2) From 1992 to 2003, IT applications concentrated on manufacturing management, such as CIMS[29], digital control system, plant management system and financial management.

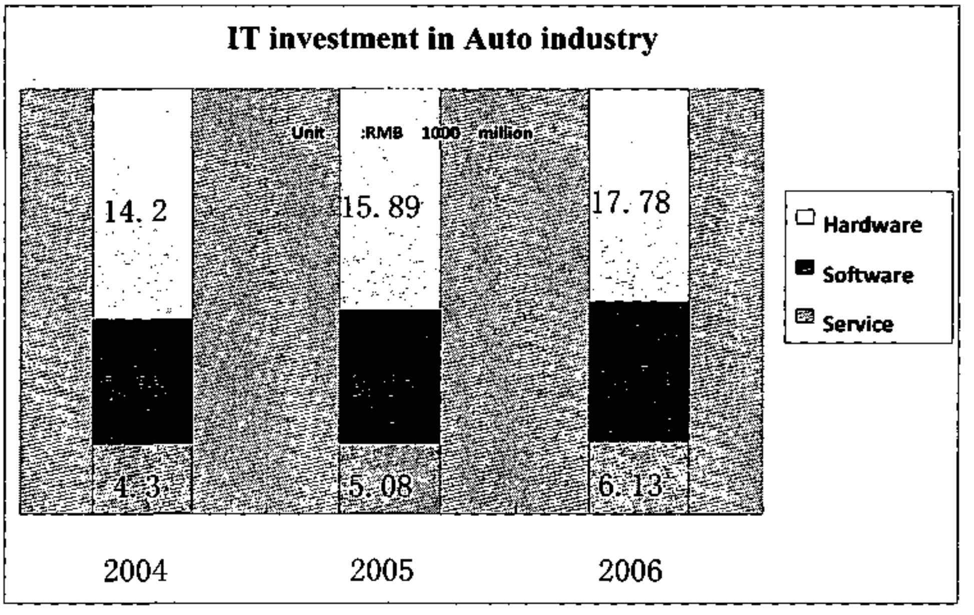
3) Since 2003, IT applications used on management, such as ERP[30], electric-business, SCM[31]

As shown from the IT investment structure in the Chinese automotive industry (see figure 6-6), in 2006, total IT investment is 3.57 billion, accounting for 4.6% of the vehicle industry profit. While the hardware investment is 1.78 billion, taking up 49.87% of total IT investment, software investment is 1.17 billion, taking up 32.93%. In 2007, IT investment in the automotive industry is 4.12 billion, growing 15.5%. The industry continues to make significant investments in modernizing IT infrastructure and application. However since 2007 the growth ratio of IT investment has slightly dropped down every year, and the growth ratio has reduced from 17.2% to 3.1% (Wei, Yan et al. 2009) (see figure 6-7).

---

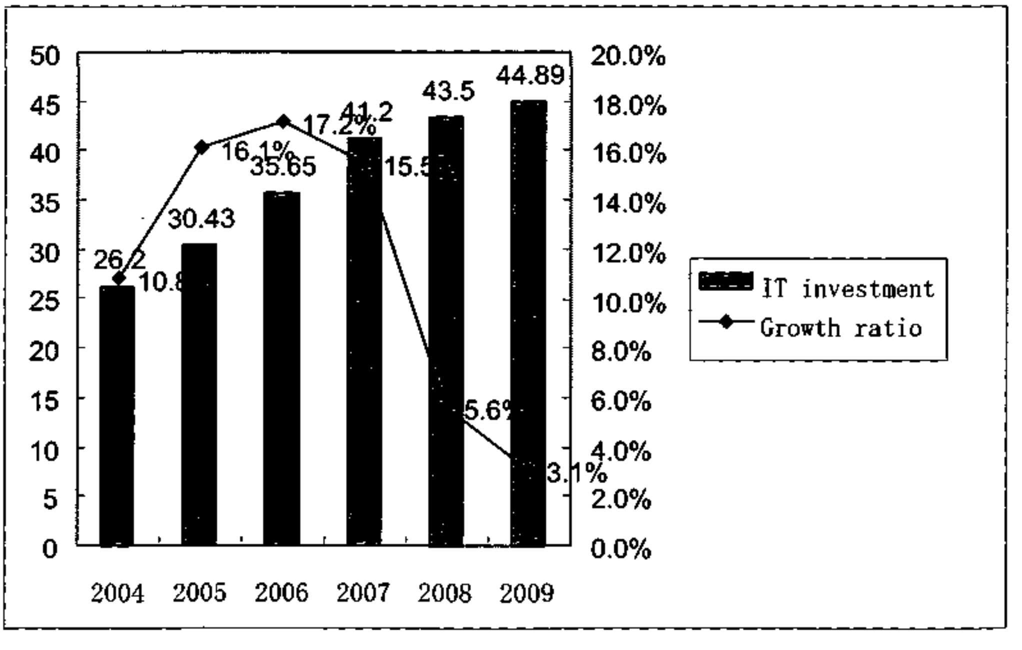
[29] CIMS is computer integrated manufacture system
[30] ERP is enterprise resource planning
[31] SCM is supply chain management

Figure 6- 6: IT investment structure



Source: Wei and Yan et. al (2009)

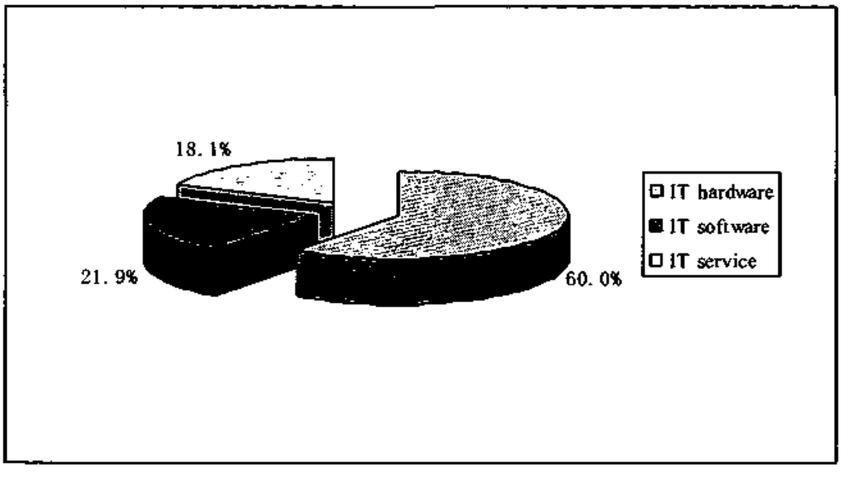
Figure 6- 7: IT investment and growth ratio from 2004 to 2009



Source: Wei and Yan et. al (2009)

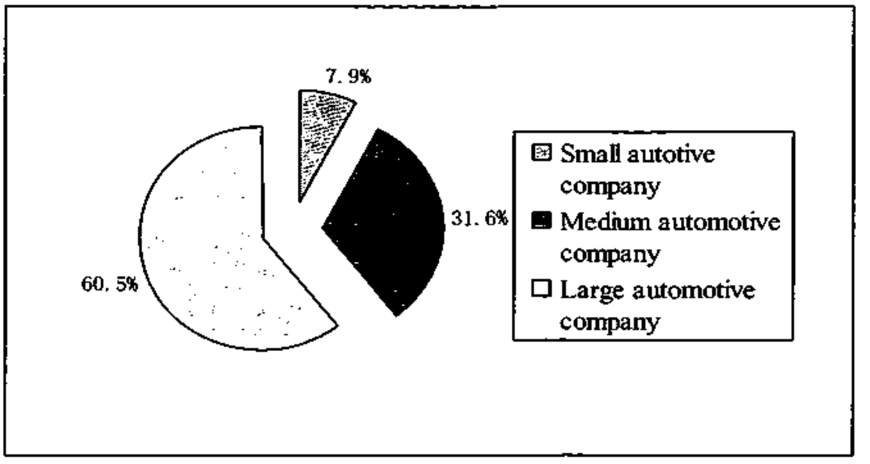
In 2009, IT investment is 4.49 billion, in which IT service accounts for 18.1% and software and hardware separately takes up 21.9% and 60% (see figure 6-8). In these IT investments, 60% is coming from big auto manufacturers, 31.6% comes from medium auto manufactures, and only 7.9% comes from small auto manufacturers (see figure 6-9) (Wei, Yan et al. 2009; Xu and Tian 2009). In recent years, the key IT system applied to the automotive system is the ERP system (Chen and Liu 2006). According to research undertaken at the Hubei College of Finance and Economics, ERP systems have increased 27.5 % in 2007 and mostly have been widely applied in large automobile enterprises and large parts manufacturers (Cai and Shi 2007).

Figure 6- 8: 2009 IT investment structure



Source: Xu and Tian (2009)

Figure 6- 9: 2009 IT investment



Source: Xu and Tian (2009)

In 2004, FAW-Volkswagen took the lead in implementing SAP/R3[32] to integrate customers, manufacturing and distributors during material procurement, production, finance, sales, spare parts and customer management (Li 2003). In 2007, Chang'an Auto Company implemented an e-business suite from Oracle - the complete set of Oracle products include Oracle database, ERP, CRM and SCM (Tech Republic 2006). Also, Jianghuai auto (JAC) has deployed the ERP system in two branches, and ERP applications cover its suppliers and retailers.

The research summaries the most popular IT software which has been implemented in the automotive upstream supply chain and downstream supply chain, these include:

- ERP system: standardizing the supply chain operations and improving efficiency.

[32] SAP R/3 is the former name of the main enterprise resource planning software produced by SAP AG.

- Production and manufacturing system: establishing agile manufacturing environment.
- SCM/E-procurement system: reducing the material and auto parts procurement cost.
- CRM system: increasing customer satisfaction.
- Sales management system (part of electronic-business): strengthening sales competence.
- Product data management (PDM) / Product lifecycle management (PLM) services include consulting, development and the integration services
- Operation system (OA): improving operation efficiency.

6.4 From a human resource management perspective

In this part, the research analyses automotive supply chain performance from two aspects: employee satisfaction ratio and employee training utilization rate.

6.4.1 Employee satisfaction ratio

An employee satisfaction survey conducted by Shandong Institute of Business and Technology in 2006 showed that big companies did not produce a high employee satisfaction ratio (Zhang 2006). According to the survey sample of 500 companies, small or medium companies have a higher employee satisfaction ratio than big companies. In companies which have less than 30 employees, 88% of employees are satisfied, in companies which have employees between 70 to 100, the employee satisfaction ratio drops to 77%, and for companies having employees more than 100, the average employee satisfaction ratio is only 65 % (Zhang 2006).

Employee satisfaction affects employee productivity, and satisfied employees are more likely to be creative and innovative. If employees are satisfied, they produce quality performance in optimal time and this leads to growth in company profits. According to the research, in 2007 the average employee productivity in the automotive industry is 1.82 which means each employee makes 18.2 thousand yuan (around US$ 2661) profit for the automotive company, and the average customer satisfaction ratio is only 77.68 % (See table 6-5).

Table 6- 5: Empirical data on human resource management

Full name	Employee training rate	Employee productivity	Salary growth rate	Employee satisfaction ratio
Shanghai Automotive	10.00%	6.35	7.60%	83.00%
FAW-Sihuan	14.50%	0.75	8.00%	81.00%
Dongfeng	6.60%	0.42	5.00%	75.00%
Chang'an Auto	8.30%	2.20	7.00%	78.00%
Beijing Automotive	10.00%	0.86	11.30%	79.60%
Huachen	7.00%	1.30	6.50%	74.70%
Fafei	5.00%	0.89	4.80%	72.50%
Average	8.77%	1.82	7.17%	77.69%

Source: the author

The research points out the main employee' dissatisfied areas based on the investigation:

1) Overwork and low rewards

Ge (2008) indicated Chinese automotive companies have developed rapidly, and employees have to overwork frequently, especially in times of product promotion or when the Chinese Spring festival is approaching. Bing Wang, an assistant manager in Tianjin Toyota Automotive Company, indicated that employees have to over work more than 60 hours every month, and employees regularly worked at nights and on weekends without extra pay.

2) Workplace and Work Environment

During observation, it was found in the automotive companies, because of financial limitations, many employees have to share small offices, companies cannot provide a comfortable workplace in terms of office equipment, furniture and so on. Other facilities, such as rest room, coffee room or education library are also not widely available for employees.

3) Inspiring leadership

Good atmosphere in the workplace affects employee satisfaction too. During the communication with employees, the research found most automotive managers are not appreciative of their employees' hard-work, and managers focus on profit rather than employee welfare. Otherwise employees feel managers fail to give them support to succeed on the job, such as motivation encouragement, experienced supervision, and necessary specific training.

In order to improve employees' satisfaction, several strategies for improvement are proposed:

Firstly, automotive companies should gain a better understanding of employees' needs and perceptions, making the reward system consistent with their performance and giving employees more work-life balance and flexibility.

Secondly, it is recommended that managers should improve or enhance management communication skills and leadership style, especially in the area of performance evaluation, such as reward and recognition.

Thirdly, employees agree that they spend a lot of time on doing low-value work that is a waste of time. Thus the research encourages automotive companies to offer training programmes making employees feel more appreciated and obtain better career prospects. It not only improves employee skills and increases their productivity, but also helps to broaden employees' experiences and satisfies their need for personal growth (Fang and Gong 2008).

6.4.2 Training utilization rate

The automotive industry is a fast changing industry, and companies must constantly adjust the training programmes to meet marketing requirements, thus training is necessary for employees to constantly improve and develop. Qiao (2009) and Weng et al.(2009) classified training programmes which are currently used in automotive companies as:

- Training for development: in order to build a motivated team, automotive companies developed several management courses for employees, such as sales strategy, budget management, enterprise culture and so on.

- Training for profession: improve employee's knowledge to use advanced technology and enhance employee skills, such as vehicle quality inspection, engineer design, procurement system cost accounting, material resource management system.

- Training for personal improvement: employees' optional training for individual needs, such as company's platforms and standards, company's systems and regulations, English study, Microsoft Office, and so on.

Automotive companies provide training programmes to help employees gain comprehensive management skills and technical skills, however to some extent, the research considers automotive companies place more emphasis on special manufacturing operations training rather than supply chain professional training. Empirical data shown employee training in terms of the supply chain management rate is 8.77% (see table 6-6) which means employees have 20 training hours every month. Standards released by the China Federation of Logistics Certification Center indicate the eligibility requirements for the standard level of supply chain certification need to ensure 72 training hours, for medium-advance supply chain specialty, the eligibility requirements are at least 150 hours (Wu and Zhao 2004). Actually, in the automotive industry, specific training programmes for supply chain management is generally less than half of this.

Table 6- 6: Empirical data of human resource management

Metric	Employee training rate (M20)	Employee productivity (M21)	Salary growth rate (M22)	Employee satisfaction ratio (M23)
SAIC	10.00%	6.35	7.60%	83.00%
FAW-Sihuan	14.50%	0.75	8.00%	81.00%
Dong feng	6.60%	0.42	5.00%	75.00%
Chang'an	8.30%	2.20	7.00%	78.00%
Beijing Automotive	10.00%	0.86	11.30%	79.60%
Huachen	7.00%	1.30	6.50%	74.70%
Hafei	5.00%	0.89	4.80%	72.50%
Average	8.77%	1.82	7.17%	77.69%

Source: The source

There are several issues which should be under consideration during training programme implementation. Thus suggestions for supply chain management training programme are:

Firstly, professional training is considered for new employees only, and some automotive companies lack long-term planning for training programmes. Many factors affect the training programme, such as financial support and the marketing and economic environment. Thus the research encourages automotive companies to set up long-term training schedules associated with a company long term strategy. Hu and Zhang (2007) further indicated that training packaging should include long-term strategy planning, budget planning, and programme scheduling.

Secondly, many automotive companies invite trainers from different centers, and these participants are not familiar with the employee's skill level and cannot identify training needs. Thus it is advocated that Jin and Bai's (2007) recommendations are taken that training programmes should place more emphasis on specialized skills rather than broad expertise for the automotive industry.

Thirdly, the research found many automotive companies only choose lecture delivery for employee training, and actually there are many more training methods which can be applied, including job rotation training, role playing and simulation training, and apprenticeships. Thus automotive companies should try to use more training methods to attract employees and improve training implementation in the *future.*

As most managers recognize that continuous training is essential, employee training programs provide focused training to employees with diverse training methods. It helps to improve employee capability and stimulate operation efficiency.

6.5 Summary

In the previous chapter, the research ranked the seven automotive companies according to their final scores and made comments on each automotive company' supply chain management. In this chapter, the research analyzed supply chain performance from these perspectives: customer perspective, financial perspective, infrastructure perspective and human resource management perspective. In the next chapter, further analysis of automotive supply chain management based on the weaknesses of companies' operational performance will follow and attempts made to propose some suggestions for future development.

Chapter 7 Improvement suggestions for supply chain management

In the previous chapter, the weaknesses of Chinese automotive supply chain performance were pointed out and analyzed. In this chapter, some suggestions to help supply chain management improvement in the future from four perspectives will be proposed: managers' conception and support, high supply chain cost, long delivery time and supply chain standardization.

7.1 Managers' conception and support

Compared to other developed countries, supply chain management in the Chinese automotive industry still lags behind. During the data collection and interviews, it was found that the primary factor hampering supply chain development is that managers lack efficient knowledge on supply chain management, thus the research categorized issues into two: deficiency knowledge of supply chain management and deficiency knowledge of supply chain performance measurement.

7.1.1 Managers' conception on supply chain management

The research discovered that many practitioners realized that supply chain management can reduce the cost for manufacturers and increase value to customers, however most managers lack efficient knowledge on automotive supply chain management and more generally do not know how to improve supply chain management. According to a supply chain survey conducted by the University of Nankai, sampling 135 managers who are engaged in the automotive industry, only 55.5 % respondents were satisfied with automotive supply chain management, 27.3 % respondents were considered supply chain operations still need to do more to reduce costs and improve efficiency (Chen and Yun. 2006). In recent years, many automotive manufacturers have promoted investment in employee training, however they are more concerned with external market demand rather than internal management improvement. Take an example of First Automotive Works (FAW)'s education and training center. It has six programmes including automobile engineering and design, electrical equipment technical training, and experimental machine design, whereas there is no specific school for supply chain management (First Automotive Works Website 2008). Thus the research assumes top managers and executives place higher priority on either automotive production or automotive market strategy, and supply chain management is considered less important.

7.1.2 Managers' conception on supply chain performance measurement

It was also identified that performance measurement is still immature in China, and there are still no formal principles and regulations in respect of measurement for supply chain management. The 2007 China Supply Chain Progress Survey showed more than half of managers only know performance measurement as a means to determine the efficiency of supply chain operations, and are unaware of performance measurement as a means to improve supply chain management. The results of the survey indicated that only 28.90% manufacturers set supply chain performance improvement as a strategic objective, and 73.11% of manufacturers have no formal long-term training programme for executives (Yuan and Jiang 2007). Top managers have not given sufficient support to it and only use performance measurement as part of human resource management to measure employee's capability. The research advocated Fan and Xin' (2005) view that the manufacturer manager should pay sufficient attention to integrating performance measurement into the whole supply chain management to stimulate supply chain evolution and improvement.

7.1.3 Solutions for improvement

In order to improve the current situation in the Chinese automotive industry, the research suggests that improvements could be undertaken as follows:

Firstly, without reliable supply chain management professionals, automotive manufacturers cannot remain competitive. In China, there are less than 8% of supply chain skilled professionals who are engaged in the automotive industry compared with more than 30% in developed countries (Shen 2008), and supply chain professionals are in short supply, The Asia Times reported the demand for supply chain professionals with university qualifications will be 300,000 to 400,000 by 2010, and more than a million workers in the Chinese logistics industry will require on-the-job training by 2010 (Yuan 2008). Thus supply chain considers education should be developed and reinforced.

At the present time, there are 218 Chinese universities with supply chain degree programmes, however this is far from enough to meet the market demand (Wenzhou University 2008). Therefore it is recommended that some automotive manufacturers fund their own business school to educate students for specific industrial needs. Take an example of Chery Automotive Company. In 2006, Chery founded its own business school to provide students with relevant academic and vocational supply chain management principles, skills and knowledge (Chery Website 2006).

Secondly, automotive manufacturers should introduce short-term or long-term education and training for employees instead of recruiting educated professionals. Manufacturers need to provide support centres for managers and employees who are looking to advance their career in the supply chain area.

Thirdly, it is recommended that the automotive industry and supply chain association, Automotive Trade Association, the China Federation of Logistics and Purchasing, should provide professional support and take an advisory role to promote supply chain management development. Associations may promote efficient supply chain management through a wide range of activities such as workshops or seminars or a regular meeting sharing successful cases and experience (Wei 2007; Zheng and Su 2008). In 2007, Supply Chain World Conferences offered a forum in China for professionals to discuss issues and trends in supply chain management and delivered presentations regarding the latest innovations, practices and new technology (Guo, Miao et al. 2007).

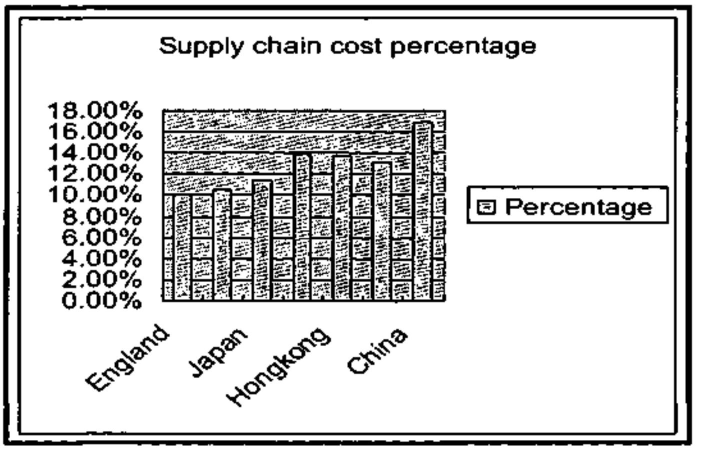
In the coming future, Chinese automotive manufacturers should be able to share their experience with international automotive manufacturers, helping them to develop the necessary competencies for efficient supply chain management.

7.2 High supply chain cost

According to international standards, supply chain development can be assessed by using the percentage of supply chain cost to gross domestic product (GDP). The lesser percentage indicates the more advanced development of the supply chain. In 2007, supply chain cost occupies around 16.9 % of Chinese gross domestic product, while in Japan it is 11.4 %, and in the United Kingdom it is only 10.10 % (Wang 2008) (see table 7-1).

Table 7- 1: Supply chain cost percentage

Country	Percentage
England	10.10%
American	10.50%
Japan	11.40%
Singapore	13.90%
Hongkong	13.70%
Taiwan	13.10%
China	16.90%



Source: Wang (2008)

Statistics from China Chamber of Commerce revealed that in 2007, the total profit of the automotive industry was more than 60.4 billion yuan, which was an increase of 62.89 % compared to the previous year (Xiao and Rong 2008). The Chinese automotive supply chain cost takes up more than 15 % of the total sales while it takes up only 5 % for the Japanese automotive industry and 8% for automotive manufacturers in Europe. According to the statistics, Chinese manufacturers' supply chain investment returns are less than 10 % and the cost of supply chain transportation is three times more than American and European (Jiang and Han 2008). High production, high supply chain cost, and low profit are a dilemma for Chinese automotive supply chain management. In the following section, the main issues are analyzed and possible solutions for high transport cost and high inventory cost provided.

7.2.1 High cost of transport

According to the data provided by the third party logistics federation, it was discovered that vehicles were transported from the province of Chang Chun to the province capital Guang Zhou, a distance of around two thousand kilometers. Each vehicle cost is about 3800-4000 yuan by using trucking transport while using water transport would be about 2500-2800 yuan. Water transport can save up to one-third cost compared to trucking transport. However, in practice, most manufacturers and suppliers select trucking delivery, which is the main mode of vehicle transport in China taking 83 % of market share. Water transport takes 12 % and railway transport accounts for less than 5% (Dai 2008; Wang 2008). Trucking delivery is very flexible for point-to-point delivery and more reliable and less damaging than rail delivery. However, trucking delivery incurs more costs than rail for long distance.

Zhang (2007) and Bowersox and Closs (2002) stated that there are the four transport modes available for vehicle delivery—railway delivery, trucking delivery, water delivery and air delivery:

- ***Railroad***

  Railroad is an efficient transport mode to delivery large or bulk products over long distances. It is suitable for low-value, high density products rather than small loads, and the typical commodity is coal or grain. In recent years, unit trains have been frequently used for the automotive industry, which can be routed direct and non-stop from origin to destination. The unit train delivery is faster and less expensive compared to traditional trains.

- ***Trucking***

The extensive development of roads and highways has supported the growth of trucking delivery. In comparison to railroads, trucking transport incurs a relatively small fixed investment, and manufacturers prefer trucking transport because they are flexible in the ways that they can be operated on all types of roadways.

- ***Water***

The main advantage of water transport is the capability to deliver extremely large shipments at low cost and it is the best choice for international vehicle delivery. However the main disadvantages of water transport are the limited range of operation and slow transit time.

- ***Air***

The least utilized transport mode is air transport. The significant advantage of air transport is high speed. Air transport can deliver products in only a few hours while other modes need several days. When the marketing period for products is extremely limited, such as sales promotion or product exhibitions, air transport maybe the most practical transportation method to use.

Bowersox et al. (2002) compared the four transport modes with respect to speed, availability, dependability, capability, and frequency:

- *Speed--- refers to the delivery time from origin and destination point.*
- *Availability--- refers to the ability of a mode to service at any location. Truck delivery has the greatest availability since highways cover the nation, even in the rural area.*
- *Dependability---refers to the transport modes potential variance from delivery schedules. Air transport has the highest score because it is can be interfered with due to weather or air congestion.*
- *Capability---refers to the ability of a mode to handle any transport requirement, such as load size. Water transport is the most capable mode.*
- *Frequency---refers to the frequency of delivery.*

Bowersox et al. (2002) compared four transport modes by ranking them 1 (number one), 2 (number two), 3 (number three), 4 (number four). Take an example of speed, air transport is considered as the fastest transport mode to deliver goods from origin and destination point, so it is ranked number one. Truck transport is slower than air, and following it ranks number two. Railway needs time to pack and transfer, and so it is slower than truck transport, ranking number three. Water transport is the lowest transport mode compared with the others, so it is given number four. Bowersox et al. (2002) used the same method to compare the four transport mode characteristics which are shown in Table 7-2:

Table 7- 2: relative operating characteristics by mode

Operating Characteristics	Railway	Truck	Water	Air
Speed	3	2	4	1
Availability	2	1	4	3
Dependability	2	1	3	4
Capability	2	3	1	4
Frequency	3	1	4	2
Composite Score	12	8	16	14

- Lowest rank is best

Source: Bowersox et al. (2002)

As shown in the chart, it is clear why trucking delivery is prevalent in the automotive supply chain. Honda in Guang Zhou almost entirely relies on trucking delivery. Joint-venture manufacturers, Faw-Volkswagen only utilizes 10 % transport by water, and North-East auto manufacturer only uses less than 15 % transport through the Chang Jiang River[33]. Niang and Bo (2007) suggested that since the oil price is soaring, water transport and railway transport costs have become much less than trucking transport.

Thus the research suggests manufacturers might consider changing the use of the single transport mode to intermodal transport to maximize the potential benefit of other transport. Combining modes include shipping-truck delivery and water-rail delivery. Take an example of shipping-truck delivery, for long distance vehicle delivery, manufacturers can select shipping delivery sending vehicle from manufacturing to main retailers in different province, then vehicles are sent to other small cities from

[33] The Changjiang River (also called the Yangtze River) is the longest river in China. It has a length of 6300 kilometers and a catchment area of 1.8 million square kilometers, which equivalent to 1/5 of the total land of China.

main retailers by trucking delivery. Manufacturers choose transport modes according to practical need, and shipping delivery can save transport cost, however in some small cities, transport infrastructure is still underdeveloped. Trucking delivery is flexible to operate and provides faster delivery time.

At present, 70 % of manufacturers are located in coastal areas, such as Changchun, Beijing, Shanghai, Guangzhou or near river areas, such as Chongqing. Manufacturers can therefore often attempt using navigable inland waterways and sea or river ways to reduce cost. Up to the end of 2006, 18 large rail container centers have been developed and managed in 18 major cities in mainland China (China economic review 2007). They possess professional knowledge and provide professional services. Thus the research supports manufacturers to take rail transportation and rail-shipping intermodal transportation to reduce the costs and other interruptions during delivery.

7.2.2 High inventory cost

The second fact that contributes to high supply chain cost is inventory cost. In order to buffer demand uncertainty, manufacturers keep safety stock as inventory. James Zhang, manager in supply chain departments at Dongfeng automotive company pointed out that production cost only accounts for 60 % of the total vehicle cost, while transportation and inventory take up to more than 30 %. Zhou and Li (2009) defined manufacturers' inventory as raw material, component parts, work-in-process, and finished goods. For manufacturers, inventory management is risky. Shanghai Association of Automotive Industry suggested that, in 2007, the inventory for the automotive manufacturers is more than 170 thousand units, and the cost associated with maintaining inventory is around 17 billion yuan (Huang 2007), that includes:

- *Basic cost: capital cost for having warehouse space and taxes*
- *Spoilage: products are sold at a discount or discarded, product value lost to obsolescence.*
- *Damage to inventory: damage lost in storage and handling.*
- *Handling of excess inventory: cost for move and storage products*

Managing inventory is important to ensure high customer service quality, however inventory is a very costly asset to maintain. According to USA national standards, inventory cost can take up 10% to 30 % of product cost (Chen and Yang 2006), and having the right amount of inventory to meet customer requirements is critical. Therefore the research attempts to propose two approaches to reduce inventory costs across the supply chain from retailers and suppliers:

Approach one: building a trusted partnership

The Lean Logistics Centre (Logistics Press 2008) reports that substantial improvement in manufacturer-retailer communications can significantly reduce inventory cost. However in practice, due to financial data confidentiality and shortage of trust, competitive information is unlikely to be shared between manufacturers and retailers, and that causes the manufacturers to have to stock certain products for uncertain demand, and this increases the capital cost tied in inventory. Thus manufacturers and retailers should develop a long term and high level trusted relationship.

It is clear as well that a closer relationship with retailers enables automotive manufacturers through web-enabled information systems to track and monitor product movement, create better forecasts, optimize their production according the actual demand and better manage inventory.

Approach two: Inventory management

In the traditional supply chain, because of a lack of information communication, the forecast and demand information is delayed and distorted. As a result the participants along the supply chain, such as suppliers, manufacturers, and retailers, have their own inventory. Now, with the development of information systems, data is easily transferred between the retailer and supplier, therefore the research advises that the automotive manufacturers should shift the ownership of inventory from manufacturers to suppliers. The suppliers take more responsibility to determine both the inventory levels and delivery frequency to maintain stock levels. The suppliers can access the system to track past sales history, sale trends, out-of-stocks records and other data, and it helps to maintain service levels and reduce inventory and costs.

7.3 Long delivery time

According to the research investigation, the average manufacturing time for vehicles is only 4.5 days (calculated as 8 working hours a day), however the average delivery time is 5.4 days, and the longest delivery time is up to 10 days (see table 7-3) The long time for vehicle delivery has become one of the challenges faced by the Chinese automotive industry. In this section, the reasons that cause long time delivery are analyzed and possible solutions identified from three perspectives: long supply chain distance, low delivery efficiency and transportation structure improvement.

Table 7- 3: Empirical data of vehicle delivery time and cycle time

Company	The average delivery time	Longest delivery time	Shortest delivery time	Order cycle time
SAIC	4.5days	7.5 days	2 days	9.5 days
FAW	5days	9 days	2.5 days	11 days
Dongfeng	4days	7 days	1 days	10 days
Chang'an	6.5 days	9 days	2.5 days	12.5 days
Beijing Automotive	5 days	8 days	3.5 days	12 days
Huachen	6days	9.5 days	3 days	13 days
Fafei	7days	10 days	3 days	13.5 days
Average	**5.4 days**	**8.6 days**	**2.5 days**	**11.6 days**

Source: The author

7.3.1 Long supply chain distance

Vehicle delivery takes so long because of the long supply chain distance along with automotive parts procurement, automotive production, automotive package and delivery. In Japan, the average distance between auto parts suppliers and automotive manufacturers is 183.3 km. For Toyota, the distance is only 95.3 km, Daimler Chrysler is 875.3 km, Ford is 818.8 km and General Motors is 682.2 km (Fang, Gong et al. 2006; Fang and Gong 2008). However in China, the average distance between suppliers and manufacturers is more than thousand kilometers, suppliers are located in various provinces, and automotive materials take several days to deliver (Yinghong and Bin 2008). Meanwhile, manufacturers try to gain a greater market share, with automotive dealers and customers covering the nation, but this also causes long lead time and high cost in terms of transportation. Consequently the research suggests that the network for the vehicle supply chain should be scientifically and logically designed. In order to improve the situation, an approach can be assessed as:

Firstly, manufacturers should reduce the number of automotive suppliers', using new selection criteria to determine whether to increase or terminate such relations.

Secondly, manufacturers should build stronger bonds with suppliers, locating suppliers nearer and integrating suppliers as a part of the manufacturing process. Rational supplier location arrangements can help manufacturers efficiently manage the supply chain, and stimulate information transfer, and also it can reduce *delivery time and inventory cost.*

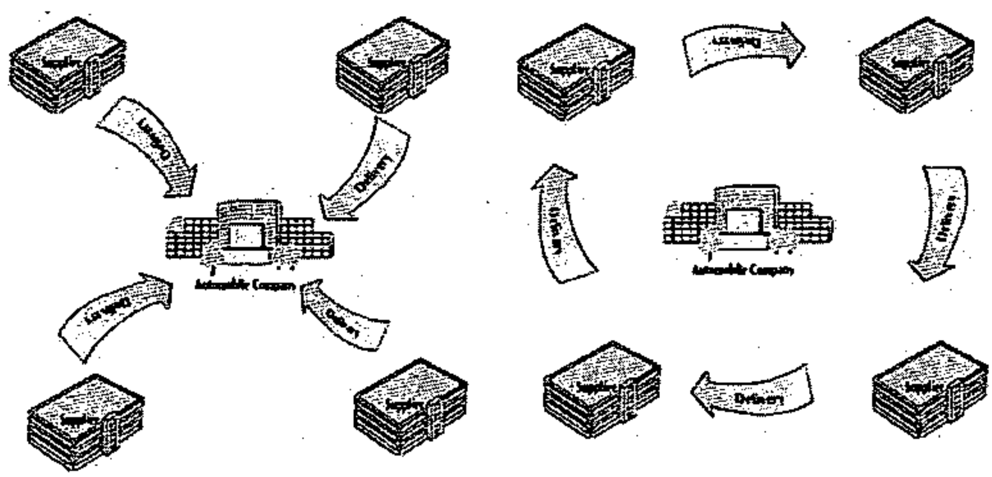
7.3.2 Low delivery efficiency

The research results suggest that the second factor causing long delivery time is low delivery efficiency. In accordance with the statistics by Wuhan University of Technology from more than 52 enterprises, the national empty-loaded delivery rate is 37 %, and the transport capacity utilization is below 75 % (Sahay and Mohan 2006). In order to handle supply chain activities efficiently, the research advocates manufacturers to consider using external companies to perform logistics functions, a company can set up a company's own logistics subsidiaries, or it can outsource the supply chain function to a third logistics party.

Take an example of ShangHai General Motor (GM) which is a joint venture between Shanghai Automotive Industry Cooperation and General Motors. At present, ShangHai-GM produces four types of vehicles with 5400 auto parts and 180 suppliers located nationwide. Everyday, every auto part supplier delivers their products direct to the manufacturer, and the one-way delivery causes empty-loads on the way back. In order to reduce delivery time, the GM manufacturer hired a third party logistics provider to arrange a transport line, named "cycle delivery". The delivery schedule is as follows (Figure 7-1): the transport line is a circle which is available to most long-distance auto suppliers. Every morning, transport trucks set off from

Shanghai-GM according to a designated route. The truck drivers then pick up prepared parts from the first auto suppliers, and then to the next auto suppliers, then to the third auto part suppliers. The truck drivers then load the auto parts from multiple suppliers, until the truck is full. The auto parts are finally delivered to the manufacturer. This is a kind of just-in-time pickup and delivery originally developed in Japan. Since the third party logistics implemented cycle delivery, GM have reduced delivery cost by 30 % and stimulated efficient management (Song and Chen 2006).

Figure 7- 1: Before and after auto parts delivery arrangement



Source: Song and Chen (2006)

Now third party logistics are being used by many manufacturers, such as Chang'an Automobile Co., Ltd., Chang'an Ford Mazda Automobile Co., Ltd., Chang'an Suzuki Automobile Co., Ltd., Volvo Automobile Co. Ltd. However, compared with the USA where third parties take up 57 % of the whole supply chain industry, and 80 % in Japan, in China independent third parties only take up 26.7 % of the whole supply chain while more than 62 % supply chain practices are operated by manufacturers' own transport and 11.3 % supply chain operation outsourcing to suppliers (Lu, Xia et al. 2006). Wu (2006) and Deng (2007) classified three main types of third logistics parties that are available for the automotive industry:

- *The first type is state-owned logistics enterprises, which have been transformed to modern logistics enterprises through reorganization. This now has the biggest Chinese logistics market share.*
- *The second type is private-owned logistics enterprises. Most of these companies are operated by Hong Kong and Taiwan logistics enterprises.*
- *The third type is foreign-funded logistics enterprises. Worldwide famous multinational logistics enterprises have successively entered into China's logistics market.*

Third party logistics is a more professional approach and offer customization of product and service to customers. Its function has moved from simple storage to provide innovative supply chain solutions to customers by focusing on value-added capabilities. The service includes: transportation management, value-added warehousing and distribution, and supply chain engineering and design services. Thus in the future, automotive companies should be encouraged to take more professional logistics services to improve supply chain efficiency.

7.3.3 Transportation infrastructure improvement

Up to 2007, China has developed a highway transportation network of 3.46 million kilometers (see table 7-4), 2.58 million kilometers longer than reported in the first national highway survey in 1979 (see Appendix 14). The length of national railways in operation had reached 75 thousand kilometers (see Appendix 15). The number of ten-thousand-ton berths in coastal ports (see Appendix 16) was 940, and the length of navigable inland waterways was more than 123.3 thousand kilometers. Infrastructure like railway, highway, water carriage, airport, and freight hubs have been improved considerably (see Appendix 17) (Jia and Luan 2007; Zhang 2007).

In recent years, transportation infrastructure and equipment have shown remarkable development, however compared with developed countries, transportation infrastructure in China is still lagging behind and it is clear that the government should build a stable and efficient transportation environment to support the supply chain industry development.

Table 7- 4: Highway development in China

Highway Development	National Highways	Provincial Highways	County Roads	Township Roads	Total Mileage
Mileage	133,355 km	239,580 km	506,483 km	987,608 km	3.46 million km

Source: Zhang (2007) and Jia and Luan (2007)

With the development and improvement of infrastructure, the automotive manufacturers can be more flexible in choosing inter-modal transport to transfer vehicles between different locations. This will not only help vehicle manufacturers to maximize economic benefits, but also increase transport capacity and supply chain efficiency.

7.4 Supply chain standardization

7.4.1 Current situation in the automotive industry

Many factors contribute to manufacturers' low profit return and long delivery time, however, Hou and Zhu (2006) claimed that supply chain standardization can help to reduce the operation cost and speed up supply chain processes for automotive companies. Wu (2006) described that in China, the supply chain standards are arranged according to the "Chinese Normative Arranging Code", including the area such as "general", "agriculture", "medicine", "machine", "railroad", "shipping" and so on. That is to say, the supply chain standards are based on the division of the administration system instead of social economic activities.

Take privately-owned Chery Automobile Co. as an example. In 2007, Chery produced 380.8 thousand vehicles, ranking top seven in vehicle sales. Its cheapest vehicle price is 23200 yuan (around 3392 US$), but the delivery time from Shanghai to Africa may take several months and the shipping cost charged up to 6530 yuan (around US 955 dollar). Lin and Yao (2006) found the main factor in the high transport cost and long time delivery is the lack of a container transportation standard. The standard of transportation containers may belong to the field of "general", but in practice it may also belong to "railroad", "shipping", or "road". During water shipping, the standard containers size are mainly 40* (in length), 8* (in width), 8* (in height) or 20* (in length), 8*(in width), 8*(in height). But on the railroad, container standard sizes are different. Consequently unnecessary intermediate links and delays are created.

The research found that manufacturers have to use a number of different transport modes at one time to deliver vehicles over long distances. It involves assembly and dissembly frequently, and it results in the unnecessary waste of packaging cost, storing fees and delaying the process. Also the research discovered there are no specific supply chain standards for the automotive industry. Existing systems already belong to several different administration systems and are not easily changed. Thus, developing new standards which fit to the automotive supply chain standard system is necessary for manufacturers.

The situation for automotive supply chain standardization was analyzed and the problems summarized are:

1) The separation of supply chain administration departments results in the disunity of standards. It brings big problems to develop supply chain standardization in the automotive industry.

2) At present, much emphasis has been put on constructing fundamental supply

chain facilities instead of supply chain management education. As Guang yuan He, general manager in the supply chain department of Dongfeng Motor Corporation said, only the integration of supply chain facilities and technology can lead to more advances in supply chain operation.

3) Also the research analyzed the reasons for slow progress of supply chain standardization development are: firstly the policy that is in favor of development of supply chain standardization has not been formed yet. Secondly Chun's (2006) arguments are relevant in that some important internationalized supply chain standards still have serious technical problems during operation, such as the accuracy rate of applying Unit Bar-code of Storage and Delivery standards is under 85%.

4) Finally it was considered that the existing supply chain standards are stale and lacking systemization. The national supply chain standardization system in China is still to be established and perfected. Jun-jie and Ning (2007) noted that the UK has 2500 related standards in supply chain management, Germany has 2480, and USA has 1200. However China has not formed a complete national supply chain standard system yet, and Lin (2007) proposed up to 2006, only 330 national standards have been published (see table 7-5).

Table 7- 5: China national standards

National supply chain standards	Item Number
Supply chain equipment standards	40 Items
Supply chain technology standards	36 Items
Supply chain management standards	153 Items
Supply chain information standards	101 Items
Relative supply chain standards	27 Items
Total:	330 Items

Source: Lin (2007)

7.4.2 Possible solutions for standardization

For developing automotive supply chain standardization, these suggestions should be taken into account:

1) First of all, as mentioned in the previous part, there is no policy for supply chain standardization. This causes serious issues, including the fact that the number of national standards are less than other developed counties and supply chain standards' technology still needs to improve. Consequently it is suggested that the government should support the automotive industry developing independently industrial standards, and the particular demands on automotive supply chain activities should be emphasized. Zhao's (2008) suggestions in to building standardization for the automotive industry are recommended:

- Hardware term: establish standards which are used for vehicle transportation, storing, loading and handing, packaging and distribution management

- Software: establish standards for information technique and application, such as electronic data interchange (EDI) application, modern information and communications technology (ICT) and so on.

- Function: establish standards for supply chain service and quality standard.

2) Secondly, it was identified that the existing supply chain standards in China are more focused on the standardization of operation, and the standards of automotive supply chain system construction, management, information, service, development etc. are further lacking (Wang and Zhang 2007). In early 2004, the China Federation of Logistics and Purchasing organized more than twenty vehicle manufacturers and logistics companies to spend three months on researching and publishing "Regulations of Transportation Service for Passenger Vehicles (Code number WB/T1021-2004)" (Industrial standards 2004). They are the first supply chain standards specific for the automotive industry to be published. It is also suggested that supply chain standardization should be based on merging the domestic supply chain with the international supply chain standards. The reasons are: First Chinese supply chain standards can learn and borrow from other developed counties' technology and skills. Also merging standards together helps to eliminate the technical obstacles existing in international trade, and simplify the development of international trade.

3) Thirdly, carrying out the supply chain standards for automotive companies produces low financial returns in the short time. Many manufacturers are not willing to upgrade professional equipment and technology. Thus it is recommended the government educates manufacturers to recognize that supply chain standardization can bring them more profits. They should also be given as much financial support as much as possible, for the sake of the entire industry, leading to coordination and implementation of supply chain standardization.

7.5 Summary

The previous chapters demonstrated AHP application in the automotive supply chain evaluation and analyzed the weaknesses of performance from customer service, financial return, infrastructural investment and human resource management perspectives. In this chapter, the research proposed some suggestions on improving the weaknesses of supply chain management, developing management concepts and support, reducing supply chain cost and delivery time, and setting up supply chain standardizations. These suggestions were based on a study of seven automotive companies with regards to their practice of supply chain management. They are associated with the implementation of supply chain management, and could help supply chain management improvement and development for the Chinese automotive industry in the future.

Chapter 8 Conclusion

Chapter 8 summarizes the main points of this research from five ways: the first part lists the contributions of the research. The second part makes a summary from the research methodology and the third and fourth part make a summary from the performance analysis and suggestions for supply chain management improvement separately. And in the final part, the research points out the limitations of the research and proposes some suggestions for future research.

8.1 Contributions of the research

The research integrates the specific framework with the analytic hierarchy process for evaluating and analyzing the automotive supply chain management in China. During the study the following objectives have been achieved:

1) Detailed research on automotive technology application, financial analysis and market strategy, supply chain management and its performance is rare and needs more exploration. The research summarizes the limitations of the existing research with regard to supply chain operation in the Chinese automotive industry:

    - The existing research is superficial and provides an overview of supply chain management in the automotive industry and introduces supply chain performance measurement rather than performance evaluation. It is mainly developed from theoretical work and lacks support from practical data and case studies. Thus the research still needs practical verification.

- Many researchers only presented uni-dimensional views of supply chain management. The existing research is very narrowly focused on three main areas: supply chain management technology, such as e-procurement software application in automotive companies; supply chain management software, such as investigation of automatic logistics system function; or single aspect new supply chain management, such as observation of inventory management.

- Many researchers only evaluate supply chain management based on a company or few companies. The existing research compares and contrasts two or three sample companies' supply chain performance. The evaluation is developed from a limited sample of companies, and thus the reliability and depth of this evaluation still needs to be confirmed.

Compared to the previous research, this research evaluated the automotive supply chain performance in China based on seven sample automotive companies: Shanghai Auto Industry Corporation (SAIC), China First Automotive Works-Sihuan (FAW), Dongfeng Motor Corporation (DFM), Chang'an Auto Co, Ltd, Beijing Automotive Industry Holding Co. Ltd, Huachen Automobile Holding Co. Ltd, and Hafei Motor Co. Ltd. These companies represent 70.8% of Chinese automotive sales in 2007. The research evaluated these representative companies by integrating AHP with a significant empirical study. The investigation of the Chinese automotive industry covers the whole supply chain operation from several aspects which include strategic supply chain management evaluation, supply chain operation evaluation, and tactical supply chain evaluation. The investigation includes communication with experts, empirical data collection from sample companies, and considerable complementary data and information from public resources and academic research. A comprehensive and specific investigation captured a more accurate representation of Chinese automotive manufacturers and their supply chain activities.

2) After performance evaluation, the research identified and analyzed the weaknesses of the supply chain operations. Very little research on the analysis of weaknesses of Chinese automotive supply chain management has been carried out, and the research is similar and has common limitations: first the analysis tended to be developed from the researcher's perception and experience or literature on Chinese automotive supply chain management. To some extent, their view is subjective and controversial. Meanwhile as automotive supply chain management was developed rapidly, some analyses are stale or shallow, lacking updated news and practical data. Also analyzers commonly only simply pointed out the weaknesses but have not given any recommendations for future improvement. The analysis of this research not only pointed out the weaknesses of supply chain operations from several perspectives, including customer perspective, financial perspective, infrastructural

perspective and human resource management but also identified the determinants behind the deficiencies and proposed some improvement alternatives. Compared to previous studies, the analysis of the evaluation is deeper and the suggestions proposed practical and effective. The research presents all the main issues associated with supply chain operations and proposes suggestions in simple and practical ways. Suggestions can be used to improve supply chain management according to a company's strategy and needs.

3) The final objective of the research is to develop a balanced measuring framework specific for Chinese automotive performance evaluation. Some studies have explored supply chain management performance evaluation mentioned in the previous section, such as Performance of Activity (POA) proposed by Felix T.S Chan and H.J. Qi (2003), A. Gunasekaran and Ronald E. McGaughey's framework (2004), and Performance Measurement Questionnaire (PMQ) proposed by Dixon and Nanni (1990). The limitations of these theories are: they are not specific for the automotive industry, they still need to be tested in practice, it is difficult to collect data, or they are not simple to be used. Thus the research attempted to develop a new framework specific for the automotive industry from the literature and practical experience. The framework proposed was based on these principles: integrating input and output metrics, addressing the relationship between determinants and results, consideration of a company's strategy and different participants, balancing the financial and non-financial metrics and supporting

continuous improvement. The framework has advantages: firstly the evaluation framework is specific for the automotive companies and is developed from the literature review and tested by practice. Secondly, the framework is very flexible, managers can consider company's condition, culture and strategy, and automotive managers can adjust evaluation metrics according to the evaluation objective. Also the calculation of evaluation is relatively simple. Managers can calculate the results manually or using a variety of softwares, such as Microsoft Excel and Expert Choice. Thirdly, the framework in form of hierarchy structure clearly presents different perspectives of supply chain operations, and the relative weight of each metric shows the relationship between metrics, sub-metrics and sub-sub-metrics. The hierarchy structure is easy to understand and helps managers to identify operational issues. Finally, the framework is operable and practical. Experts' scales can be calculated through communication with professionals who can be selected either from automotive companies or academic institutions. And the metrics are flexible to change or modification if data cannot be collected for some reason.

8.2 Summary from methodology

Obtaining effective and reliable data and information is vital to calculate the current supply chain management practices in the Chinese automotive industry currently. Thus it is crucial to assess the research philosophy and select appropriate research methods to investigate the research and meet the research objectives. An interpretivism philosophy was selected because it was exploratory which research uses small-scale sample automotive companies to explore the practical supply chain management in the Chinese automotive industry. The research defined issues associated with the operations and proposes some suggestions based on a better understanding of the environment within which the issues occurred (McDaniel and Gates 1999).

There are two basic research approaches available: deductive and inductive methods. Inductive research moves from data to theory, by collecting the data first and then developing new hypotheses as a result of the data analysis. Thus the inductive approach was appropriate for this particular research.

There are three research strategies used in this research: survey, case study and phenomenological study. Data in this research was collected from a variety of different sources:

Sample Selection

There are hundreds of automotive companies in China, and it is impossible to collect data from them all, and therefore the seven top companies were selected as samples.

Top companies have advantages in terms of data collection, they are public companies, and more empirical data is available in newspapers and journals.

Interview

Interviews can obtain the in-depth information relative to the participants' experiences, perception and views. Semi-interview is in the form of communication between the researcher and interviewees. The research uses the interview method to acquire specific answer related to the implementation of supply chain management, such as the expert's view on supply chain management challenges and their suggestions for improvement.

Primary data and secondary data

The primary data was collected from automotive companies. The secondary data from public sources, such as books, published and internal journal articles, reports and on-line news. Books were a general resource to provide relevant theory support for the study. Public Journals are a useful resource for analysis and suggestion while supply chain association internal journals provided professional views. On-line news can provide the latest data and development in the particular area of study.

Observation

Observation consisted of a tour to retailers and manufacturers. The aim of this method is to verify and complement other data and information, and collect some empirical data, such as customer satisfaction ratio.

The research uses Huo and Ma's method (2002) to filter and adapt the data. The reasons for its application are: firstly some of the empirical data shows many differences, for example the Shanghai Automotive Industry Corporation (SAIC) sales growth ratio is 2182.7% while Hafei Motor Co. Ltd is only 6.29%. The research also quantified empirical positive and negative data. It transferred companies' empirical data into analytical data in the range between 【0, 1】 for AHP calculation. Excel software was used in these calculations.

Also in order to avoid unwanted side-effects to the final results when data, financial data in particular, are not available, the research calculated other metrics such as the percentage or ratio, which are easier to calculate and analyze, and can be used to represent company conditions. The research also had to choose an alternative company -the biggest completely-owned subsidiary- FAW Sihuan Automotive Co as a representative for China First Automotive Works Group (FAW) instead of the main company to continue the investigation.

8.3 Summary from the research analysis

Analysis in this research can be divided into: general analysis and further analysis. The general analysis in chapter 5 was based on the individual company study, and it focused on each company's characteristics through comparisons between them. The further analysis in chapter 6 is a summary of the whole industry in terms of its advantages and disadvantages through comparison with other developed countries, such as Japan and the USA.

General analysis

In chapter 5, the research firstly demonstrated supply chain management evaluation procedures and calculation. The research ranks seven companies according to their final performance score. Then the research presents clear empirical data comparisons and indicates each company's advantages on each metric. The research also traces the reasons for which companies' achieved high scores on performance. The research presents each company's new developments on managerial philosophy, and hardware and software improvements and advanced technology applications to support the analysis. Timely news and companies' reports are quoted for the analysis.

Further analysis

After studying each company individually, the research further analyzes and summarizes the whole Chinese automotive industry in chapter 6. The further analysis is accessed from four perspectives: the customer's perspective, the financial perspective, the infrastructural perspective, and the human resource perspective. The research pointed out the strengths and weaknesses of automotive supply chain management, and attempted to trace the reasons that led to the weaknesses. Compared with developed countries, the research analyzes Chinese automotive industry specific characteristics from these four perspectives:

The research analyzed from a customer perspective, and presented and analyzed customer satisfaction for new product development, vehicle price and design, and customer dissatisfaction about out of stock and long waiting time. Reasons causing out of stock are: some automotive and parts need to be imported from other counties and some new vehicle models are in high demand. The research encouraged automotive companies to build pre-caution systems, and found that long delivery times were common and unacceptable.

From a financial perspective, the characteristics of high sales and profit growth, but low profit and assets return were analyzed. Even though the automotive industry has seen growth rapidly in recent years, automotive shareholders and managers still feel profit and asset return less than their expectation. The main factors causing low financial investment return were that manufacturing costs are high as are transport and inventory cost. It was suggested that automotive companies should enhance information transfer on transport management, and improve inventory management.

From an infrastructure perspective, the following supply chain operations weaknesses were identified: inefficient equipment utilization and shortage of investment on infrastructure. The research indicated that inaccurate market demand estimation leads to inefficient equipment utilization. And in terms of investment on infrastructure the investment on infrastructure increased from 35.65 million to 44.89 million, but the investment growth ratio dropped from 17.2% to 3.1% from 2006 to 2009.

Analysis of human resource management was from two aspects. Firstly, employees' dissatisfaction of low rewards and the workplace environment. In order to solve these issues, strategies for improving communication between managers and employees and satisfying employee's personal needs were needed. Secondly the automotive industry needs professionals, but employee training is deficient. Thus the research supports automotive companies in building long-term training plans, focusing on training needs and trying more training methods to improve training effectiveness.

This research was based on considerable primary and secondary data acquired from a wide variety of sources – manufacturers, retailers, customers etc. Its coverage of supply chain issues in the Chinese automotive industry has not been attempted before and as such its contribution is especially valuable.

8.4 Summary of improvement suggestions

The objectives of the research were to evaluate the performance of supply chain operations and propose some suggestions for the automotive industry future development. Thus the research is divided into two stages: performance evaluation and continuous improvement. The first phase of performance measurement analyzed the automotive manufacturers' supply chain operation strengths and weaknesses. The second phase of the research attempted to propose some improvement suggestions for the existing problems. These suggestions are:

1) During the investigation, the research found automotive managers have deficient knowledge on supply chain management and performance measurement, thus the research suggested companies should enhance supply chain education from several perspectives: as mentioned in the previous chapter, there are not enough professionals with university qualifications for the industry, thus automotive companies should build their own business school or introduce short-term and long-term education. Meanwhile the automotive industry and supply chain associations should provide more professional support for supply chain education and skill improvement.

2) The research offers suggestions for ameliorating high supply chain costs which were mentioned in the previous chapter. Four different transport modes are considered and it is suggested that automotive companies should select flexible

intermodal transport to reduce high transport costs. For high inventory cost, the research recommends automotive companies to develop closer relation with retailers and suppliers, and to reduce vehicle stock through in-time information exchange.

3) Long supply chain distance and low delivery efficiency contributed to long delivery time. For the long vehicle delivery time, the research presented suggestions: companies should scientifically and logically arrange the network of vehicle deliveries, improve delivery efficiency by considering using external companies, and also the government should improve transport infrastructure.

4) Automotive supply chain management faces the challenge of supply chain standardization. The research found that lacking supply chain standards brings a series of issues: information transfer obstacles, operational inefficiency and high operational costs. The development of supply chain standardization in China is far behind other developed counties, thus the research gave suggestions for supply chain standardization. The automotive industry should improve the existing supply chain standards, and develop its own standards. And the government should educate and encourage automotive companies to implement higher supply chain standards.

In chapter 7, the research attempts to provide meaningful managerial implications for the automotive companies. Other researchers' studies were reviewed and verifies and research was implemented through interviews with experts. To some extent, these suggestions were developed from an in-depth practical investigation and understanding of the key issues associated with supply chain operation. Compared to other studies, these suggestions are both more practical and effective.

8.5 Limitations and suggestions for future research

There can be no research without limitations. This research attempts to develop a framework which provides a critical appraisal of supply chain management in the Chinese automotive industry. The 27 metrics, sub-metrics and sub-sub-metrics have been considered by certified experts and are specific for the evaluation of Chinese automotive supply chain management. However the empirical results show that two main limitations exist:

Firstly, despite encouraging results of the non-bias tests, the research only chose convenient manufacturers as samples to evaluate the whole of the Chinese automotive industry. The limited sample number can be compared to more than hundreds of manufacturers in China at present, and the validity and reliability of data is relatively low. Thus in order to investigate more deeply into comprehensive supply chain management in the Chinese automotive industry, more broad empirical research is needed.

Secondly, the proposed framework is restricted by the objective of measuring the overview of supply chain operations. During the interviews, experts were encouraged to demonstrate their perception of supply chain performance and facilitated to reach agreement on preference for metrics that are critical to the evaluation. Since the relative weights of the criteria and sub-criteria are derived by the survey, the possibility of respondent bias cannot be ruled out. The result may vary in preferences if people have different backgrounds or are located across different departments within companies. Therefore, replication of this study with different collection methodologies and samples is needed to address these issues.

Thirdly, additional research and practically-driven initiatives are needed in the area of supply chain performance measurement. The potential benefits of integrated supply chain management should no longer be ignored. Designing new performance measurement should integrate suppliers and customers and other channel members' considerations and address their considerations and suggestions for performance measurement evaluation and improvement. .

In spite of the limitations of this study, the research presents and evaluates the actual supply chain management in the automotive industry from several perspectives: strategic perspective, operational perspective and tactical perspective. Based on the main problems involved with the current practices of supply chain management for automotive companies in China, the research also presented recommendations for

Chinese automotive companies to solve these problems and improve their performance in supply chain management. Suggestions that can be recommended for Chinese automotive managers to solve these problems relate to their supply chain management practices. Meanwhile the analytic hierarchy process (AHP) with its framework can provide manufacturers with a relatively easy methodology for operation measurement and benchmarking. The performance measurement framework is very flexible in changing metrics. The research suggests the framework may be applied with small modifications according to each manufacturer's own goals and operational strategies. Managers may also identify their own critical factors, sub-factors, sub-sub metrics and relative importance to the objective of the evaluation by experts' questionnaire.

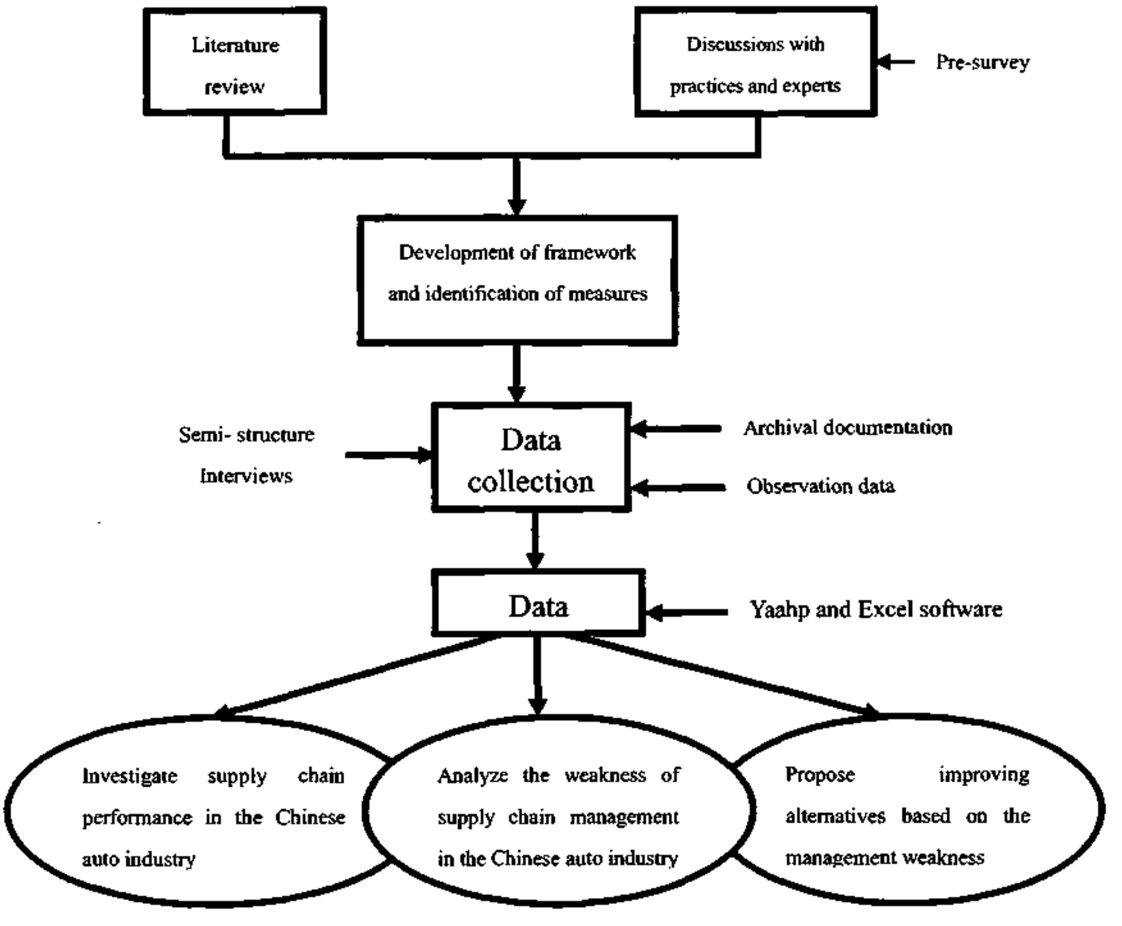
Appendices

Appendix 1: Ph.D research schedule

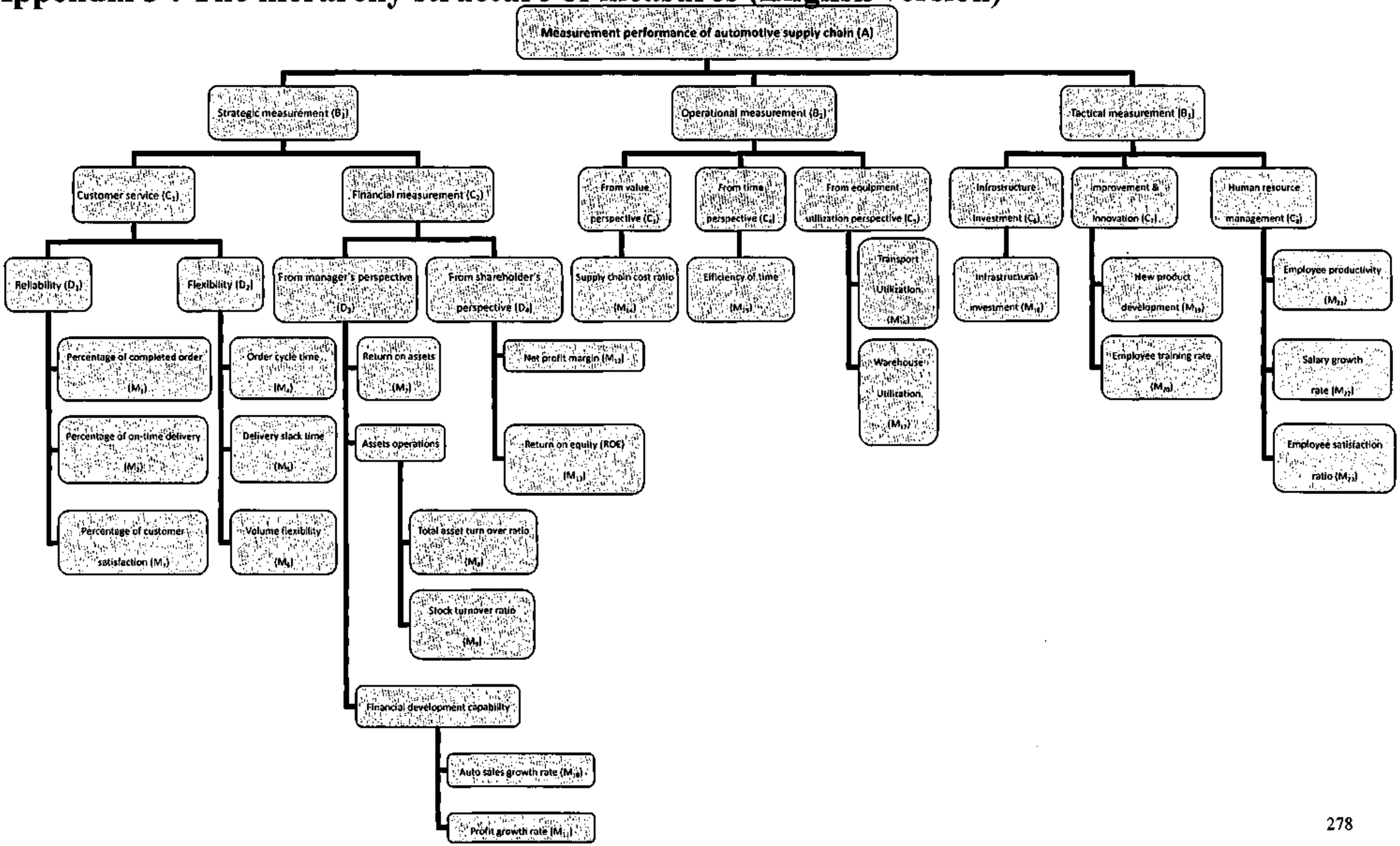
The research began in March 2006. Based on the schedule below, data was collected during the Mid-May 2008 to May, 2009, and the final report will be completed by the end of March, 2010.

Research Activity	Research Begun / Completed	Term
Choose research project	2006, March-2006, June	Three months
Research literature review	2006, Sep-2007, March	Six months
Suspended schooling	2007, April-2008, April	One year
Transfer report	2008, April -2008, Mid-May	One and half months
Plan for request form and get feedback	2008, Mid-May to July, 2008	Two and half months
Pre-survey	2008, August-2008, Oct	Two months
Modify performance metrics and formulas and design for interview and collect data	2008, November	One month
Obtain measure scale by interviewing with researchers and managers	2008, November to 2009, Jan	One and half months
Collect data from top seven companies	2009, Feb-2009, May	Four months
Data Analysis	2009, June-2009, July	Two months
Research writing up	2009, August-2010, March	Eight months
Thesis correction	2010, April-2010, June	Two months
Report delivery	2010, July	-----

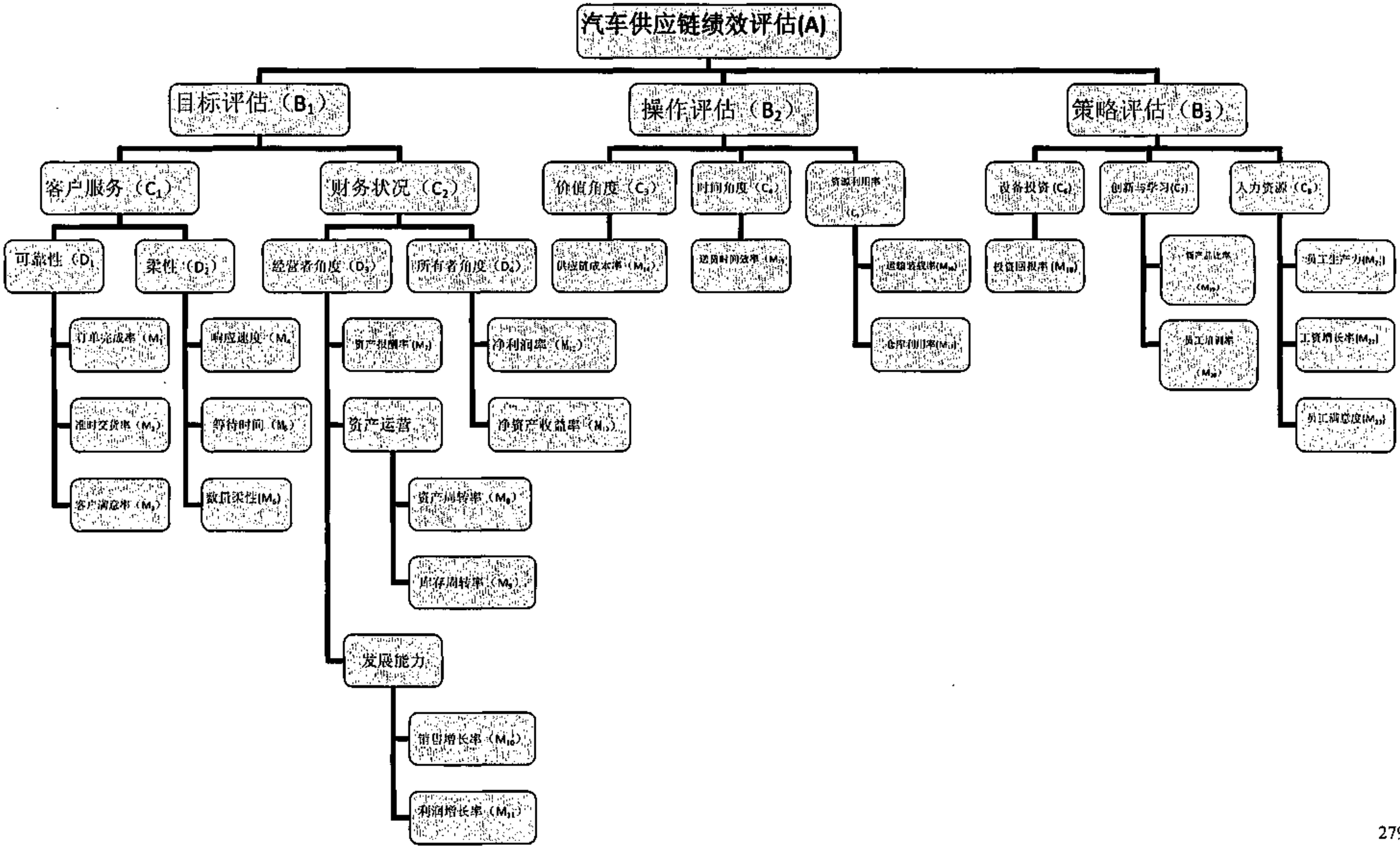
Appendix 2: Framework of PH.D research



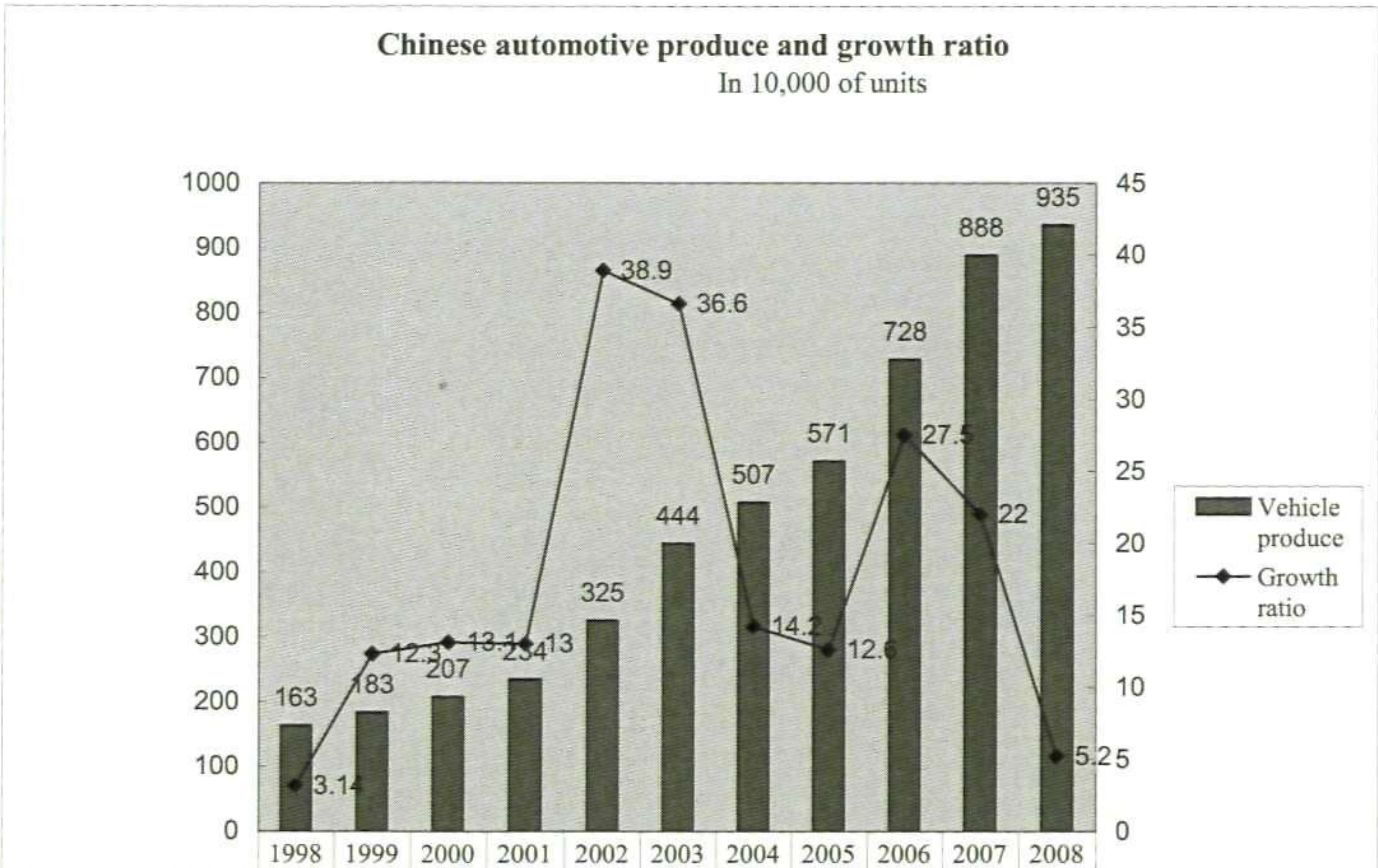
Appendix 3 : The hierarchy structure of measures (English version)



Appendix 4: The hierarchy structure of measures (Chinese Version)

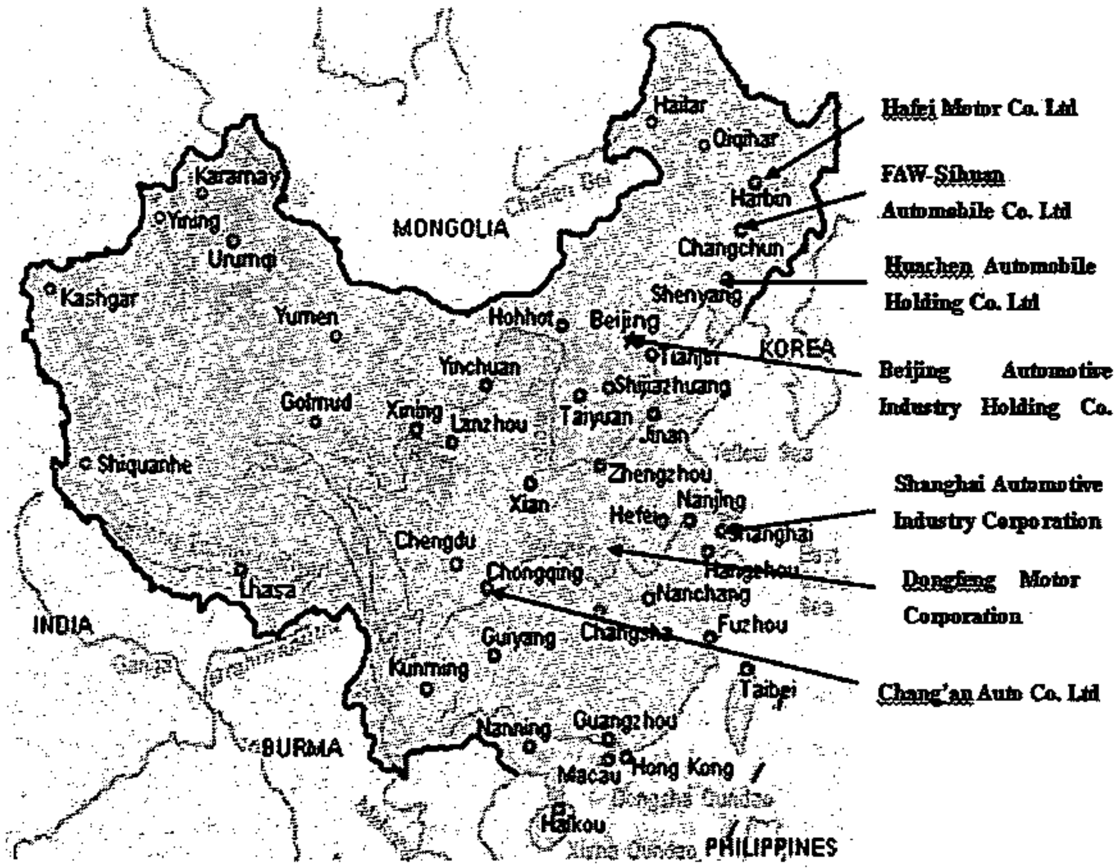


Appendix 5: Chinese automotive produce and growth ratio (from 1998 to 2008)



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Vehicle produce	163	183	207	234	325	444	507	571	728	888	935
Growth ratio	3.14	12.3	13.1	13	38.9	36.6	14.2	12.6	27.5	22	5.2

Appendix 6: Seven automotive companies' location



Source: Automotive News (2008)

Appendix 7: Pre-survey questionnaire (English version)

Pre-survey questionnaire for expert suggestions

(English version)

Dear ……..:

I am a current research student who is studying supply chain management in centre for International Shipping and Logistics at the University of Plymouth, UK. My research subject is "An empirical analysis of vehicle manufacturers supply chain management performance in China". As all of you are the experts in automotive supply chain management, I really appreciate if you could follow the instruction to complete the full set of questions.

This interview is only for the purpose of academic researching. If you have any queries about the survey, Please contact me at any time on the telephone or email address below:

E-mail: ling.wan@plymouth.ac.uk
MSN: lookfor1999@hotmail.com
UK Tel: 00 44 (0)1752 (23) 3422
China Tel: 0086-010-88550311
0086-13611177745

Thank you very much for spending your precious time to complete this survey.

Yours sincerely

Ling Wan
Centre for International Shipping and Logistics
The Business School
Room 405F, Cookworthy Building
University of Plymouth
Drake Circus
Plymouth
PL4 8AA
United Kingdom
00 44 (0)1752 (23) 3422

Instruction for the questionnaire:

The section one of questionnaire form presented a framework of automotive supply chain management performance measurement. The performance evaluation approached from three perspectives: strategic level, operational level and tactical level. Each level has a range of metrics. Such as a strategic level consisted of customer service metrics and financial metrics.

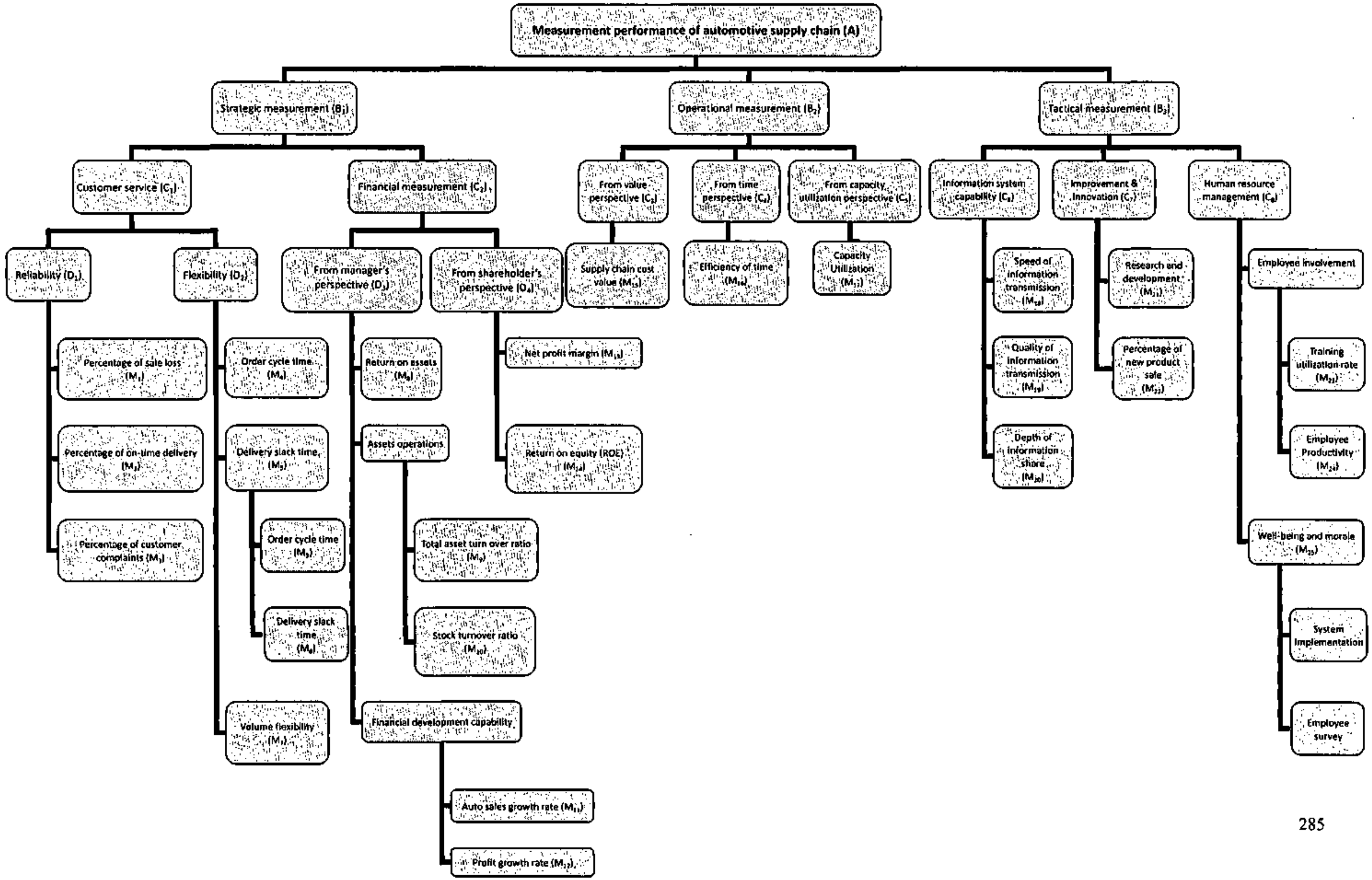
The section two of questionnaire form presented metrics with their formulas. The objective of the questionnaire is to get your suggestions on metrics choice, formulas check and data collection.

In the "metrics selection" column, if you think that a formula is reasonable, please tick the "Yes". If you think that unreasonable, please tick "No", and specify your suggestions.

In the "formula check" column, if you think that a formula is correct, please tick the "Yes". If you think that incorrect, please tick "No", and specify your suggestions.

Meanwhile, in the "data collection" column, please indicate where is easily to collect the data. D denotes automotive dealer, M denotes automotive manufacturer, S denotes automotive supplier. If you have better suggestions, please leave in the "Your suggestion" column.

The first part of questionnaire:



The second part of questionnaire:

Table 1: Strategic measures
Customer service

	Metrics	Descriptions	Formulas	Metrics selection	Formula check	Data collection	Your suggestions
Reliability	**Percentage of sale loss (M1)**	It measures whether the supply chain can meet customer needs	The ratio of the losing sale to total sales	Yes	Yes		
				No	No		
	Percentage of on-time delivery (M2)	It measures whether manufacturers supply chain can deliver product in time	The percentage of delivering on or before the promised scheduled	Yes	Yes		
				No	No		
	Percentage of customer complaints (M3)	It measures whether manufacturers' product and service can satisfy customers	The ratio of customer complaint numbers to total trade number	Yes	Yes		
				No	No		
Flexibility	**Product flexibility (M4)**	It measures manufacturers' capability on developing new products	The ratio of new product models to total models	Yes	Yes		
				No	No		

	Order cycle time (M5)	It measures whether supply chain management can quickly respond customer	The average order cycle time [34] to respond customer order	Yes	Yes		
				No	No		
	Slack time of delivery (M6)	It measures flexibility on produce deliver time	**See note 1**	Yes	Yes		
				No	No		
	Volume flexibility (M7)	It measures flexibility on manufacturer's productivity	The ratio of manufacturer's productivity to market demand	Yes	Yes		
				No	No		

[34] Order cycle time includes order entry time (through forecasts/direct order from customer), order planning time (design + communication+ scheduling time), order sourcing, assembly and follow up time, and finished goods delivery time

Financial measurement

	Metrics	Descriptions	Formulas	Metrics selection	Formula check	Data collection	Your suggestion
From	**Financial output (M8)**	It measures Pre-tax return on assets (ROA)	The ratio of pre-tax revenue to average assets	Yes No	Yes No		
	Asset operations						
	Total asset turnover ratio (M9)	It measures how well assets are being used to produce revenue.	The ratio of a manufacturer's net sale to average assets	Yes No	Yes No		
	Stock turnover ratio (M10)	It measures how well inventory is managed.	The ratio of annual sales to stock	Yes No	Yes No		
	Financial development capability						
	Auto sales growth rate (M11)	It measures manufacturers sales development capability	(2007sales-2006 sales)/ 2006sales×100%	Yes No	Yes No		
	Profit growth rate (M12)	It measures manufacturers profit development capability	(2007 profit-2006profits)/ 2×100%	Yes No	Yes No		

From shareholder's perspective	**Return on investment (M13)**	It measures return to capital invested.	Net profit / (2007 Jan revenue+2007 Feb revenue) ×100%	Yes No	Yes No		
	Economic value added (M14)	It measures the value has created for its shareholder.	Net profit/(capital × cost of capital)	Yes No	Yes No		

Table 2: Operational proposal measures

	Metrics	Descriptions	Formulas	Metrics selection	Formula check	Data collection	Your suggestion
Operational measurement	**Supply chain value added ratio (M15)**	It measures value created by supply chain	**See note 2**	Yes No	Yes No		
	Efficiency of lead time (M16)	It measures the efficiency of delivery time based on NV&NVA.	The ratio of ideal deliver time to average deliver time	Yes No	Yes No		
	Capacity of utilization rate (M17)	It measures the actually productive capacity.	The ratio of actual production to designed production	Yes No	Yes No		

Table 3: Tactical proposed measures

	Metrics	Descriptions	Formulas	Metrics selection	Formula check	Data collection	Your suggestion
Information system capability	**Speed of information transmission (M18)**	It measures the speed of demand information transmission in the supply chain	**See note 3**	Yes No	Yes No		
	Quality of information transfer (M19)	It measures the quality of demand information in the supply chain	**See note 4**	Yes No	Yes No		
	Depth of information share (M20)	It measures the depth of information sharing.	Identify if sharing information covering: forecasting, planning, order, delivery, stock, and transaction and so on.	Yes No	Yes No		
Improvement&	**Research and development (M21)**	It measures the return of investment for the future development.	The ratio of R&D revenues to R&D investment	Yes No	Yes No		

	Percentage of new product sale (M22)	It measures manufacturer's capability of research and development	The ratio of new product sale to vehicle sale	Yes No	Yes No		
Human resource utilization	**Employee involvement**						
	Training utilization rate (M23)	It measures human resource management	The ratio of trained employees to the number of total employees	Yes No	Yes No		
	Employee productivity (M24)	It measures how much output can be generated by each employee	The ratio of manufacturers' profit to the number of employees	Yes No	Yes No		
	Well-being and morale (M25)						
	System implementatio n	It measures if system exists	Check if Well-being system is existed?	Yes No	Yes No		
	Employee survey	How it is operated	Interview with some employees, questions are coving: how well-being system is implemented? If employees satisfied with well-being system? Which area need to improve?	Yes No	Yes No		

Note:

Note 1: Slack time of vehicle delivery

The research evaluates the average slack time of vehicle delivery by calculating the average gap between the delivery time to minimum delivery time for *N* times. The equation of average slack time can be expressed:

$$ST = \frac{(D_{ave} - D_{min}) \times N}{\sum_{i=1}^{N} D_i}$$

While:

D_{ave} represents the average delivery time;

D_{min} represents the minimum time of delivery vehicle;

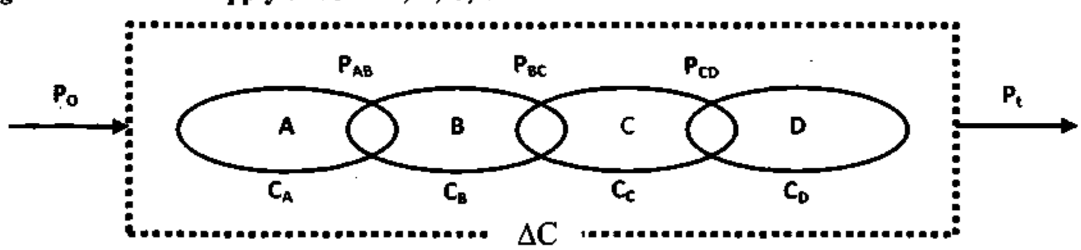
Note 2: Supply chain value added ratio

The approach to measure supply chain value is based on the assumption of a whole supply chain of four companies A, B, C, D, which is shown in Figure 1. P_0 is the price of vehicle materials, P_t is the price of finished product, and P_{AB} is the trade price between company A and B. This can similarly be applied in P_{BC}, P_{CD}; and C_A is company A's product cost, including other costs, such as operational cost and staff payments and so on.

Presuming four companies in the whole chain, the value of the supply chain can be expressed as: $\Delta P = P_t - P_0$. The cost of the supply chain is ΔC, so the supply chain value added can be calculated as:

$$R_{value} = \frac{\Delta P}{\Delta C} = \frac{P_t - P_0}{C_A + C_B + C_C + C_D - P_{AB} - P_{BC} - P_{CD}}$$

Figure 1: the whole supply chain of A, B, C, D



Note 3: Speed of information transmission

An approach to evaluate the speed of demand information transmission in the supply chain is the following: Assuming the whole automotive manufacturing process is a chain, we can select two companies with the nearest located to customer, retailer A and the furthest located to customer, supplier B to obtain the slack time for information transfer during Time *r*. The formulation for calculating the ISS as:

$$ISS = \frac{2}{|T_{ha} - T_{hb}| + |T_{la} - T_{lb}|}$$

Each structure is described using the following dimensions;

T_{ha} represents the time of the product maximum demand for retailer A during time *r* ;
T_{hb} represents the time of the product maximum demand for supplier B during time *r*;
T_{la} represents the time of the product minimum demand for retailer A during time *r;*
T_{lb} represents the time of the product minimum demand for supplier B during time *r;*

Note 4: Quality of information transfer

The paper takes an example of demand information as well. Similarly, the paper chooses retailer A which is nearest to customer and supplier B which is the furthest company to customer, comparing demanding data quality during the time *r*, the formulation for calculating the ISQ is:

$$ISQ = \frac{2 \times \overline{D}}{|D_{maxa} - D_{maxb}| + |D_{mina} - D_{minb}|}$$

Each structure is described using the following dimensions;

$\overline{D}$ represents the average product demand during the time *r*;
D_{maxa} represents the maximum product demand for retailer A during the time *r*;
D_{maxb} represents the maximum product demand for supplier B during the time *r*;
D_{mina} represents the minimum product demand for retailer A during the time *r*;
D_{minb} represents the minimum product demand for supplier B during the time *r*;

Appendix 8: Pre-survey questionnaire (Chinese version)

Pre-survey questionnaire for expert suggestions

(Chinese version)

....

您好！

我是英国普林茅斯大学物流系的学生。这次调查的目的在于对中国汽车供应链进行绩效评估.本调查问卷分为两个部分:

在第一部分，调查给出了汽车供应链整体绩效评估体系的构成，评估分为三个基本部分：目标评估，操作评估和策略评估。每个基本评估都有所属绩效评估指标，比如目标评估主要是评估客户服务和财务状况。

第二部分是各个绩效评估指标的基本量化公式，本次调查是为了取得有关专家对供应链整体绩效评估体系中评价指标的量化公式是否合理，量化公式是否正确，何处比较容易拿到数据。

在“指标选择”栏，如果您觉得量化公式合理，请在“是”后打钩，如果您觉得不合理，请在“否”后打钩，并注明您的建议。

在“公式检查”栏，如果您觉得量化公式正确，请在“是”后打钩，如果您觉得不正确，请在“否”后打钩，并注明您的建议。

同时，在“数据收集”栏，请您注明何处比较容易拿到数据，D表示汽车销售商，M表示汽车公司，S表示汽车供应商，如果您有更好的建议，也可以注明。

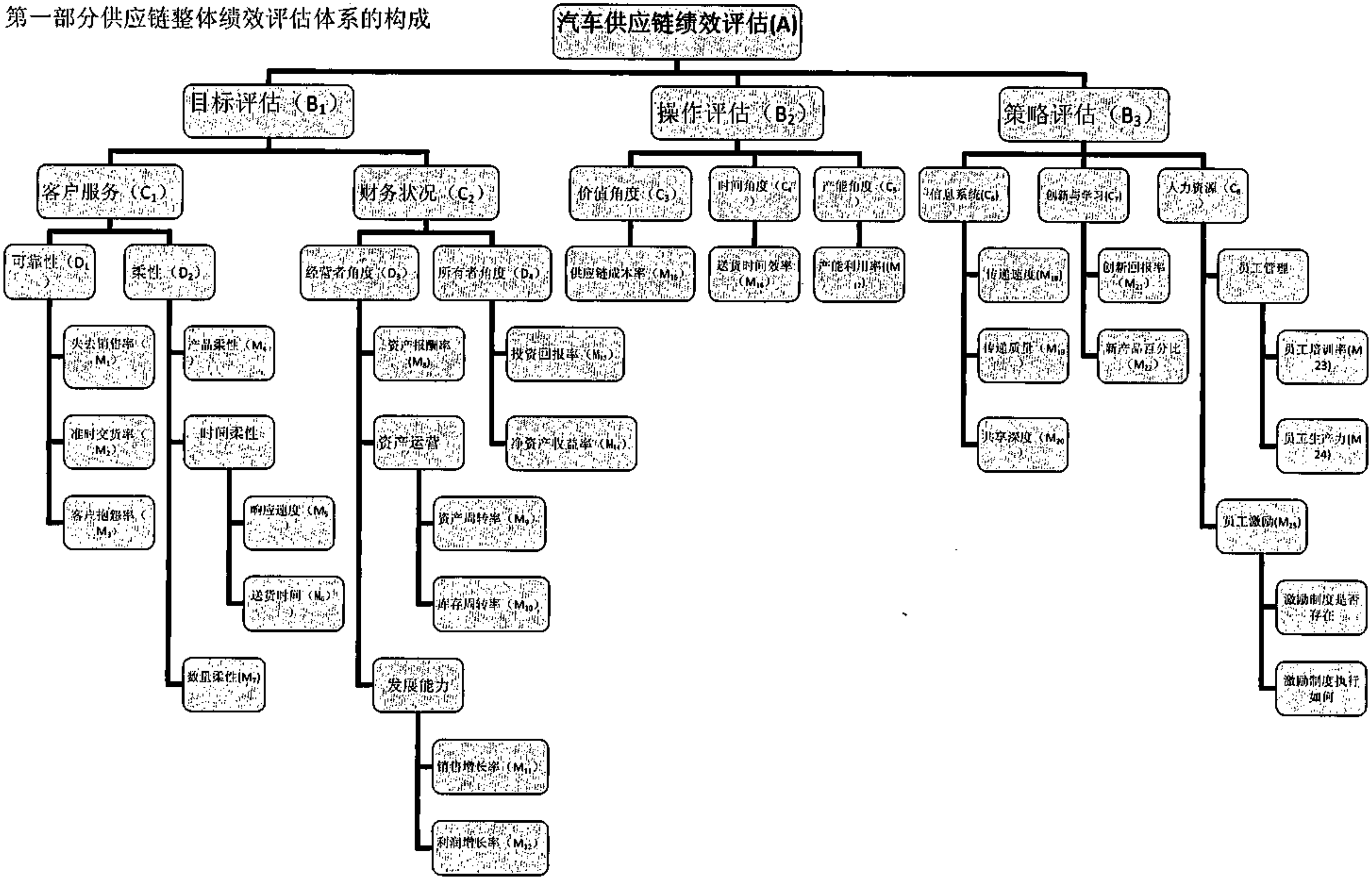
本次是以研究为目的，希望能得到您真诚的协助，如您在问卷有何疑问，请与我联系，联系方式如下：

E-mail：ling.wan@plymouth.ac.uk
MSN：lookfor1999@hotmail.com
UK Tel: 00 44 (0)1752 (23) 3422
China Tel: 0086-010-88550311
0086-13611177745

谢谢您在百忙之中可以抽出时间，为我们填写这份问卷！

万玲
Centre for International Shipping and Logistics
The Business School
Room 405F, Cookworthy Building
University of Plymouth
Drake Circus
Plymouth UK
PL4 8AA

第一部分供应链整体绩效评估体系的构成



第二部分调查问卷

表格1: 目标评估

客户服务

	评估指标	公式解释	公式	指标选择	公式检查	数据收集	您的建议
可靠性	失去销售比（M1）	供应链是否满足客户需要	失去销售额/总销售量	是	是		
				否	否		
	准时交货比例(M2)	供应链是否能够准时交货	准时交货次数/总交货次数×100%	是	是		
				否	否		
	顾客抱怨率（M3）	供应链提供的产品和服务是否客户的需求	顾客抱怨次数/总交易次数×100%	是	是		
				否	否		
产品柔性	产品柔性(M4)	新产品的引进是否可以满足客户的需求	新产品种类数/产品总类总数×100%	是	是		
				否	否		

	响应客户速度(M5)	供应链是否快速响应客户需求	平均响应客户的时间[35]	是 否	是 否		
	送货时间柔性(M6)	送货时间灵活性	详情见附注1	是 否	是 否		
	送货数量柔性 (M7)	是否能满足客户需求	可满足的客户需求/客户总体需求量×100%	是 否	是 否		

财务评估

	评估指标	公式解释	公式	指标选择	公式检查	数据收集	您的建议
从管理者角度	**财务收益(M8)**	总资产报酬率	税前利润/净资产平均总额×100%	是 否	是 否		
	资产管理						
	总资产周转率(M9)	反映企业资产盈利能力的指标	净利润/(期初总资产+期末总资产)/2×100%	是 否	是 否		

[35]客户响应时间指的是从收到客户订单到最后客户拿到车所用时间。

	库存周转率(M10)	反映存货的周转速度	年销售额/平均存货额	是 否	是 否		
	财务发展						
	销售年增长率(M11)	公司销售评估	(2007年销售额-2006年销售额)/2006年销售额×100%	是 否	是 否		
	利润年增长率(M12)	利润增长评估	(2007年利润-2006年利润/2006年利润)×100%	是 否	是 否		
从投资者角度	**投资回报率(M13)**	从所有者角度对投资回报评估	净利润/(2006年收益+2007年收益)/2×100%	是 否	是 否		
	经济附加值(M14)	对所有者创造的价值进行评估	税后净营业利润-资本占用 ×加权平均资本成本率	是 否	是 否		

表格2: 操作评估

	评估指标	公式解释	公式	指标选择	公式检查	数据收集	您的建议
操作评估	**供应链价值角度(M15)**	评估供应链生产附加值	见附注2	是	是		
				否	否		
	送货效率角度(M16)	评估送货效率	理论上送货时间/实际送货时间	是	是		
				否	否		
	产能利用率(M17)	评估供应链中多少实际生产在运转	实际产能/设计产能×100%	是	是		
				否	否		

表格3：策略评估

	评估指标	公式解释	公式	公式选择	公式检查	数据收集	您的建议
信息系统评估	**信息传递速度(M18)**	评估供应链中信息传递速度	见附注3	是	是		
				否	否		

	信息传递质量(M19)	评估供应链中信息传递质量	见附注4	是 否	是 否		
	信息传递深度(M20)	评估供应链中信息传递深度	共享信息是否包括汽车的销售预测，生产计划，送货时间，库存和交易情况	是 否	是 否		
创新与学习评估	**创新与投入回报率(M21)**	公司创新是否有良好市场回应	创新与投入产生回报/创新与回报投入	是 否	是 否		
	新产品销售收入百分比(M22)	评估公司创新能力	新产品销售额/产品销售总额	是 否	是 否		
人力资源管理	**员工评估**						
	员工培训率(M23)	公司对员工培训管理	参加培训的员工/总员工数	是 否	是 否		
	员工生产	公司员工的	公司盈利/员	是	是		

	力(M24)	生产能力	工人数 ×100%	 否	 否		
	员工福利制度(M25)						
	员工福利制度是否存在	员工福利制度是否存在，合理和完善	员工调查	是 否	是 否		
	员工福利制度执行	员工福利制度执行如何	小型员工询问调查，询问包括福利在哪些方面？是否满意福利制度？	是 否	是 否		

附注：

1. 送货时间柔性

我们评估送货时间柔性通过计算平均的送货时间D_{ave}和最短送货时间D_{min}之间的松弛时间，其计算公式量化为：

$$ST = \frac{(D_{ave} - D_{min}) \times N}{\sum_{i=1}^{N} D_i}$$

2. 供应链价值角度

汽车的供应链条有四个公司组成：A, B, C, D（如图所示），P_0是汽车成本，P_t汽车成品卖出价，P_{AB}是公司A和公司B之间的交易价，同样的，P_{BC}是公司B和公司C之间交易价，P_{CD}是公司C和公司D之间交易价。C_A是公司A的投入成本，投入成本包括运作成本和员工工资等。同样C_B, C_C, C_D分别是公司B, C, D的投入成本。

我们假设有四个公司组成的供应链中，供应链创造的价值为：$\Delta P=P_t-P_0$，供应链的成本为：ΔC, 因此供应链的生产附加值可量化为：

$$R_{value}=\frac{\Delta P}{\Delta C}=\frac{P_t - P_0}{C_A + C_B + C_C + C_D - P_{AB} - P_{BC} - P_{CD}}$$

3. 信息传递速度

汽车从订购原材料，生产到销售是一条供应链，我们分别选择一个距离客户需求信息最近的销售商A和一个距离客户信息最远的供应商B，在时间段r内，在销售商A和供应商B的两条客户曲线上找到客户需求量最大的时间点T_{ha}和T_{hb}和需求量最小的需求点T_{la}和L_{lb}, 将共享信息的传递速度ISS 量化为：

$$ISS = \frac{2}{|T_{ha} - T_{hb}| + |T_{la} - T_{lb}|}$$

4. 信息传递质量

同上述方法相似，我们分别选择一个距离客户需求信息最近的销售商A和一个距离客户信息最远的供应商B，在时间段r内，在销售商A和供应商B的两条客户曲线上找到客户需求量最大的值D_{maxa}和D_{maxb}和需求量最小的值D_{mina}和D_{minb},
将共享信息的传递速质量ISQ 量化为：

$$ISQ = \frac{2 \times \overline{D}}{|D_{maxa} - D_{maxb}| + |D_{mina} - D_{minb}|}$$

Appendix 9: List of seven interviewees

Interviewees from academic research

Name	background/research specialization	Location/Email
Rongqiu Chen	Professor, research on flexible supply chain management in the automotive industry.	Huazhong university of Science and Technology, hubei province rongqiu@mail.hust.edu.cn
Yuehua Chen	Trainer in Shanghai automotive association	Shanghai wuyun901@yahoo.com.cn
Zhiqiang Luan	Senior lecturer, doing research on marketing strategy in automotive Industry.	The University of Shangdong, ShangDong Province Zhqluan@hotmail.com

Interviewees from supply chain practice

Name	Position/Background	Email
Ming zhi Li	Director of business development	Shanghai General Motors company mingzhili@guard-group.com
Lei Ren	Senior supply chain manager	China federation of logistics and purchase Reiko_ren1999@hotmail.com
Changchun Yang	Dealer for BMW	21 century motor www.zqzj@century21.com.cn
Liyun Hou	Senior supply chain manager	Dongfeng motor corporation Bill_hou@126.com

Appendix 10: Experts scale collection form

Interview Assessment Form

During this survey, an interviewee will be asked personal view and conception on six questions regarding Chinese automotive supply chain performance measurement system. The interview questions are split up into two parts. First it will ask a interviewee to rate elements according their importance, then the second part is to evaluate the relative importance of several elements by using the nine-point scales (see note) for pair-wise comparison.

This interview is only for the purpose of academic researching. Thank you very much for your precious time.

- Name ....
- Position ....
- Affiliation...
- Contact number/Email...
- Interview Date...
- Memo

Part one: Obtain metrics importance

1. Matrix A

Q_1 Could you rate three elements according the importance of their contribution to the overall automotive supply chain performance?

B_1 Strategic measurement: evaluates the manufacturers' customer service and business potential for managers, investment return for shareholders.

B_2 Operational measurement: evaluates business operations from supply chain value, efficiency of cycle time and equipment utilization.

B_3 Tactical measurement: evaluates infrastructure investment, new product development and human resource management which support the manufacturers' efficiency operation and long-term strategy.

Result:........ $B_1>B_2>B_3$ **(template)** ....

Q_2 Could you evaluate the relative importance of the three elements by using the nine-point scales for pair-wise comparison?

Performance measurement	**1/9**	**1/8**	**1/7**	**1/6**	**1/5**	**1/4**	**1/3**	**1/2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Performance measurement**
Strategic measurement				√														Operational measurement
Strategic measurement																		Tactical measurement
Operational measurement																		Tactical measurement

2. Matrix B1

Q_1 Could you rate two elements according to their importance of contribution to evaluate strategic measurement?

C_1 Customer service: evaluates from customer service reliability and flexibility.

C_2 Financial measurement: concerned from both operation managers and the manufacturers' shareholders sides to evaluate manufacturers' investment return.

Result:..

Q_2 Could you evaluate the relative importance of the two elements by using the nine-point scales for pair-wise comparison?

Strategic measurement	**1/9**	**1/8**	**1/7**	**1/6**	**1/5**	**1/4**	**1/3**	**1/2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Strategic measurement**
Customer service																		Financial measurement

2.1 Matrix C1

Q_1 Could you rate two elements according to their importance of contribution to evaluate customer service?

D_1 Reliability: evaluates from the percentage of completed order, on-time delivery and customer satisfactions.

D_2 Flexibility: evaluates from order cycle time, delivery slack time and volume flexibility.

Result:..

Q_2 Could you evaluate the relative importance of the two elements by using the nine-point scales for pair-wise comparison?

Customer service	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9	Customer service
Reliability																		Flexibility

2.2 Matrix C2

Q_1 Could you rate two elements according to their importance of contribution to evaluate financial measurement?

D_3 From manager's perspective: evaluates financial return from manager's perspective.

D_4 From shareholder's perspective: evaluates investment return from shareholder's perspective.

Result:..

Q_2 Could you evaluate the relative importance of the two elements by using the nine-point scales for pair-wise comparison?

Financial measurement	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9	Financial measurement
From manager's perspective																		From shareholder's perspective

3. Matrix B2

Q_1 Could you rate three elements according to their importance of contribution to evaluate operational measurement?

C_3 From value perspective: evaluates supply chain value contribute to manufacturers.

C_4 From time perspective: evaluates the speed of manufacturers' response to customer demands.

C_5 From equipment utilization perspective: evaluates manufacturers' equipment utilization rate.

Result:..

Q_2 Could you evaluate the relative importance of the three elements by using the nine-point scales for pair-wise comparison?

Operational measurement	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8		Operational measurement
Value perspective																		Time perspective
Value perspective																		Utilization perspective
Time perspective																		Utilization perspective

4. Matrix B3

Q_1 Could you rate three elements according to their importance of contribution to evaluate tactical measurement?

C_6 Infrastructural investment: evaluates infrastructural investment return.

C_7 Improvement and Innovation: evaluates new product development and employee training.

C_8 Human resource management: evaluates from employee productivity, and employee well-being and morale.

Result:...

Q_2 Could you evaluate the relative importance of the three elements by using the nine-point scales for pair-wise comparison?

Tactical measurement	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8		Tactical measurement
Infrastructural investment																		Improvement and Innovation
Infrastructural investment																		Human resource utilization
Improvement and Innovation																		Human resource utilization

Note: Nine-point scale for pair-wise comparison

← Less important | More important →

1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Extremely		Very strongly		Strongly		Moderately		Equally	Moderately		Strongly		Very strongly		Extremely	

1	Equally Important	1	Equally Important
2	Between Equal and Moderate Importance	1/2	Between Equal and Moderate Less Importance
3	Moderately Important	1/3	Moderately Less Important
4	Between Moderate and Strong Importance	1/4	Between Moderate and Strong Less Importance
5	Strongly Important	1/5	Strongly Less Important
6	Between Strong and Very Strong Importance	1/6	Between Strong and Very Strong less importance
7	Very Strong Importance	1/7	Very Strong Less Importance
8	Between Very Strong and Extreme Importance	1/8	Between Very Strong and Extreme Less Importance
9	Extreme Importance	1/9	Extreme Less Importance

Appendix 11: Automotive manufacturers' empirical data collection form (English version)

Chinese automotive supply chain data collection

This Chinese automotive supply chain data collection is due for my research in "An empirical analysis of vehicle manufacturers supply chain performance in China", company confidential commercial data guarantee will be used **only** for doctor of philosophy research.

Please do not hesitate to contact Ling Wan at any time with queries about the topics related to vehicle supply chain management on the telephone or email address below.

Ling Wan : Email Address: ling.wan@plymouth.ac.uk
Telephone Number: 0044-7756364909 (UK)
0086-13611177756(China)

Thank you very much for your assistance!

Participant list

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Data in 2007, passenger vehicle particular

Serial number	Metrics name	Data source[36]	Metrics	Data collection	Comments
M_1	Percentage of completed order	M,R	The number of completed orders in 2007		Why does not meet customer orders?
			The total number of customer orders in 2007		
M_2	Percentage of on-time delivery	M,R	The number of on-time deliveries in 2007		Why can't vehicle be delivered on-time?
			The total number of product deliveries in 2007		
M_3	Percentage of customer satisfaction	M,R, C	The number of customer satisfactions in 2007		What are customers complaining about?
			The total number of vehicle sales in 2007		
M_4	Order cycle time	M, R	The average cycle time to respond to customer order		The order cycle refers to the time between receipt of customer order and final delivery to customers.
			The cycle time of producing a vehicle		
M_5	Delivery slack time	M	The average delivery time in 2007		
			The longest delivery time in 2007		
			The shortest delivery time in 2007		
M_6	Vehicle volume flexibility	M	the number of vehicle produced by manufacturers in 2007		
			the total number for market demand in 2007		
M_7	Pre-tax return on assets (ROA)	Financial report	The initial pre-tax revenue in 2007		
			the final pre-tax revenue in 2007		
			the initial total assets in 2007		
			the final total assets in 2007		
M_8	Total asset turnover ratio (ATO)	Financial report	A manufacturer's net sales (revenues) in 2007		
			A manufacturer's total assets in 2007		
M_9	Stock turnover ratio	Financial report	The number of manufacturer's stock turnover		
M_{10}	Auto sales	Financial	The sale of vehicles in		

[36] S refers suppliers; M refers manufacturers; R refers retailers; C refers customers

	growth rate	report	2007		
			The sale of vehicles in 2006		
M_{11}	Profit growth rate	Financial report	the profit of manufacturers in 2007		
			the profit of manufacturers in 2006		
M_{12}	Net profit margin	Financial report	the net profit of manufacturers in 2007		
			the sales revenue of manufacturers in 2007		
M_{13}	Return on equity	Financial report	The initial pre-tax revenue in 2007		
			The final pre-tax revenue in 2007		
			The initial total equity investment in 2007		
			The final total equity investment in 2007		
M_{14}	Supply chain cost ratio	**M**	The cost of manufacturer supply chain management in 2007		
			The total vehicle sales in 2007		
M_{15}	Efficiency of delivery time	**M**	The ideal time of delivery vehicle in 2007		The delivery time means the time from the receipt of orders until the product is received by customers.
			The average time of delivery vehicle in 2007		
M_{16}	Transport utilization. ratio	**M**	The total vehicle volume in 2007		
			The number of transport trucks in 2007		
			The standard volume capacity for trucks in 2007		
M_{17}	Warehouse capacity utilization ratio	**M**	The actual storage area for completed product in 2007		
			The total storage area for completed product in 2007		
M_{18}	Infrastructural investment	**M** Financial report	The profit of manufacturers in 2007		
			The profit of manufacturers in 2006		
M_{19}	New product development	**M**	The number of new vehicle models in 2007		New vehicle models include newly introduced vehicle, newly developed vehicle, redefined vehicle models, new hybrid vehicles and so on
			The total number of vehicle models in 2007, Jan		
			The total number of vehicle models in 2007,		

			Dec		
M_{20}	Training utilization rate	**M**	The total time of supply chain training programmes		
			The number of employees who were engaged in supply chain operation		
M_{21}	Employee productivity	**M**	Manufacturers' revenue in 2007		The cost includes operational cost, material cost and employees' salary and so on.
			The cost of manufacturing in 2007		
			The number of employees		
M_{22}	Salary growth ratio	**M**	The average of employee's salary in 2007		
			The average of employee's salary in 2006		
M_{23}	Employee satisfaction ratio	**M**	The ratio of employee satisfaction		What are employees dissatisfied with?

Appendix 12: Automotive manufacturers' empirical data collection form (Chinese version)

Participant list

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Name:
Position:
Company name:
Contact number/Email:
Contact address:

Name:
Position:
Company name:
Contact number/Email:
Contact address:

所有数据采用2007

序列号	供应链绩效评价指标	单位	指标数据	数据	备注
M_1	订单（正确）完成率	次	2007年订单正确完成次数		为什么无法满足客户订单？
			2007年客户订单总次数		
M_2	准时交货率	次	2007年准时交货次数		为什么不能准时交货？
			2007年交货总次数		
M_3	客户满意率	次	2007年客户满意次数		客户抱怨在什么地方？为什么会有这种情况出现？
			2007年总成功交易次数		
			2007年淘汰汽车种类数		
			2007年1月汽车种类数		
			2007年12月汽车种类数		
M_4	顾客拿货时间	天	2007年客户平均拿货时间		客户拿货时间指从收到客户订单到客户拿到汽车的时间
M_5	送货时间	天	2007年平均送货时间(运输时间)		乘用车
			2007年最长送货时间		
			2007年最短送货时间		
M_6	数量柔性	辆	2007年汽车公司生产汽车数量		乘用车
			2007年汽车市场需求量		
M_7	资产回报率	百分比			
M_8	资产周转率	百分比			
M_9	库存周转率	百分比			
M_{10}	销售增长率	百分比			
M_{11}	利润增长率	百分比			
M_{12}	净利润率	百分比			
M_{13}	净资产收益率	百分			

		比			
M_{14}	供应链成本率	现金	2007年供应链运作成本		供应链成本率=年供应链成本额/年销售额或者供应链成本/汽车成本
			2007年汽车销售额		
M_{15}	送货时间效率	小时	理论上的送货时间		
			实际操作中的平均送货时间		
M_{16}	运输装载率	辆	现实中,运输货车实际载重汽车辆		1. 运输装载率=实际载重量/标准载重量 2. 可以选用1-3种货车
		辆	运输货车标准载重汽车数量		
M_{17}	仓库利用率	米	汽车仓库存货面积		1.仓库利用率=存货面积/总面积 2. 可以选择几个仓库某段时间的平均利用率
		米	汽车仓库总面积		
M_{18}	投资回报率	万元	2007年汽车公司在物流设备软,硬件上的投资金额		
			2007年公司盈利		
			2006年公司盈利		
M_{19}	新产品研发	款	2007年新开发的车型款数		乘用车
			2007年初总车型款数		
			2007年底总车型款数		
M_{20}	员工培训率	小时	2007年供应链部门总培训员工时间		培训课程: 管理培训，技能培训和物流专业培训.
		人数	2007年参与培训人员数		
M_{21}	员工生产力	万元	2007年公司盈利		
		万元	2007公司运作成本		
		人	2007年公司员工人数		
M_{22}	工资增长率	现金	2006年物流部门员工平均工资		
			2007年物流部门员工平均工资		
M_{23}	员工满意度	百分比	2007年物流部门员工对公司福利满意度		

Appendix 13: Automotive companies' performance measurement calculation

Abbreviation:

M1 Percentage of completed order
M2 Percentage of on-time delivery
M3 Percentage of customer satisfaction
M4 Order cycle time
M5 Delivery slack time
M6 Volume flexibility
M7 Pre-tax return on assets (ROA)
M8 Total asset turnover ratio (ATO)
M9 Stock turnover ratio
M10 Sale growth rate
M11 Profit growth rate
M12 Net profit margin
M13 Return on equity (ROE)
M14 Supply chain cost ratio
M15 Efficiency of lead time
M16 Transport capacity utilization
M17 Warehouse capacity utilization
M18 Infrastructure investment
M19 New product development
M20 Employee training rate
M21 Employee productivity
M22 Salary growth rate
M23 Employee satisfaction ratio

A: the objective of performance measurement
B1: strategic performance
B2: operational performance
B3: tactical performance
C1: customer service measures
C2: financial measures
C3: from value perspective
C4: from time perspective
C5: equipment utilization perspective
C6: infrastructure investment
C7: improvement and innovation
C8: human resource management
D1: product reliability
D2: product flexibility
D3: from manager's perspective
D4: from shareholder's perspective

C1 Shanghai Automotive Industry Cooperation

Supply chain performance weighted index, empirical data and final weightiness

					A					
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	1									
M2	0.84									
M3	0.89									
M4		0.76								
M5		0.39								
M6		1								
M7			0.77							
M8			0.19							
M9			1							
M10			1							
M11			1							
M12				0.79						
M13				1						
M14					0.6					
M15						0.44				
M16							0.64			
M17							0.79			
M18								0.24		
M19									0.99	
M20									0.67	
M21										1
M22										0.76
M23										0.66
M SUM	2.73	2.15	3.96	1.79	0.6	0.44	1.43	0.24	1.66	2.42
M*D or C	0.869	0.342	0.420	0.095	0.066	0.0487	0.052	0.006	0.021	0.164
									Final Sum	2.087

C2 Changchun FAW-Sihuan Automobile Co. Ltd

Supply chain performance weighted index, empirical data and final weightiness

					A					
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	1									
M2	0.86									
M3	0.91									
M4		0.7								
M5		0.46								
M6		1								
M7			0.61							
M8			0.25							
M9			0.59							
M10			0.44							
M11			0.98							
M12				0.59						
M13				0.68						
M14					0.66					
M15						0.4				
M16							0.5			
M17							0.64			
M18								0.2		
M19									0.84	
M20									0.97	
M21										0.15
M22										0.8
M23										0.62
M SUM	2.77	2.16	2.87	1.27	0.66	0.4	1.14	0.2	1.81	1.57
M*D or C	0.882	0.343	0.304	0.067	0.073	0.044	0.042	0.004	0.023	0.106
									Final Sum	1.892

C3 Dongfeng Motor Cooperation

Supply chain performance weighted index, empirical data and final weightiness

	A									
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	0.99									
M2	0.78									
M3	0.86									
M4		0.74								
M5		0.33								
M6		0.94								
M7			0.7							
M8			0.17							
M9			0.46							
M10			0.3							
M11			0.07							
M12				0.73						
M13				0.89						
M14					0.57					
M15						0.5				
M16							0.4			
M17							0.59			
M18								0.19		
M19									0.86	
M20									0.44	
M21										0.08
M22										0.5
M23										0.5
M SUM	2.63	2.01	1.7	1.62	0.57	0.5	0.99	0.19	1.3	1.08
M*D or C	0.837	0.319	0.180	0.086	0.063	0.055	0.036	0.004	0.017	0.073
									Final Sum	1.674

C4 Chang'an Auto Co. Ltd

Supply chain performance weighted index, empirical data and final weightiness

A										
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	0.97									
M2	0.68									
M3	0.8									
M4		0.65								
M5		0.13								
M6		0.9								
M7			0.66							
M8			0.13							
M9			0.47							
M10			0.16							
M11			0.07							
M12				0.76						
M13				0.84						
M14					0.63					
M15						0.31				
M16							0.47			
M17							0.62			
M18								0.17		
M19									0.77	
M20									0.55	
M21										0.44
M22										0.7
M23										0.56
M SUM	2.45	1.68	1.49	1.6	0.63	0.31	1.09	0.17	1.32	1.7
M*D or C	0.780	0.267	0.158	0.085	0.069	0.034	0.040	0.004	0.016	0.115
									Final Sum	1.572

C5 Beijing Automotive Industry Holding Co. Ltd

Supply chain performance weighted index, empirical data and final weightiness

					A					
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	0.95									
M2	0.82									
M3	0.81									
M4		0.67								
M5		0.5								
M6		1								
M7			0.71							
M8			0.6							
M9			0.81							
M10			0.41							
M11			1							
M12				0.57						
M13				1						
M14					0.52					
M15						0.4				
M16							0.6			
M17							0.73			
M18								0.18		
M19									0.7	
M20									0.67	
M21										0.17
M22										1
M23										0.59
M SUM	2.58	2.17	3.53	1.57	0.52	0.4	1.33	0.18	1.37	1.76
M*D or C	0.821	0.345	0.375	0.083	0.058	0.044	0.049	0.004	0.018	0.119
									Final Sum	1.918

C6 HuaChen Automotive Holding Co. Ltd

Supply chain performance weighted index, empirical data and final weightiness

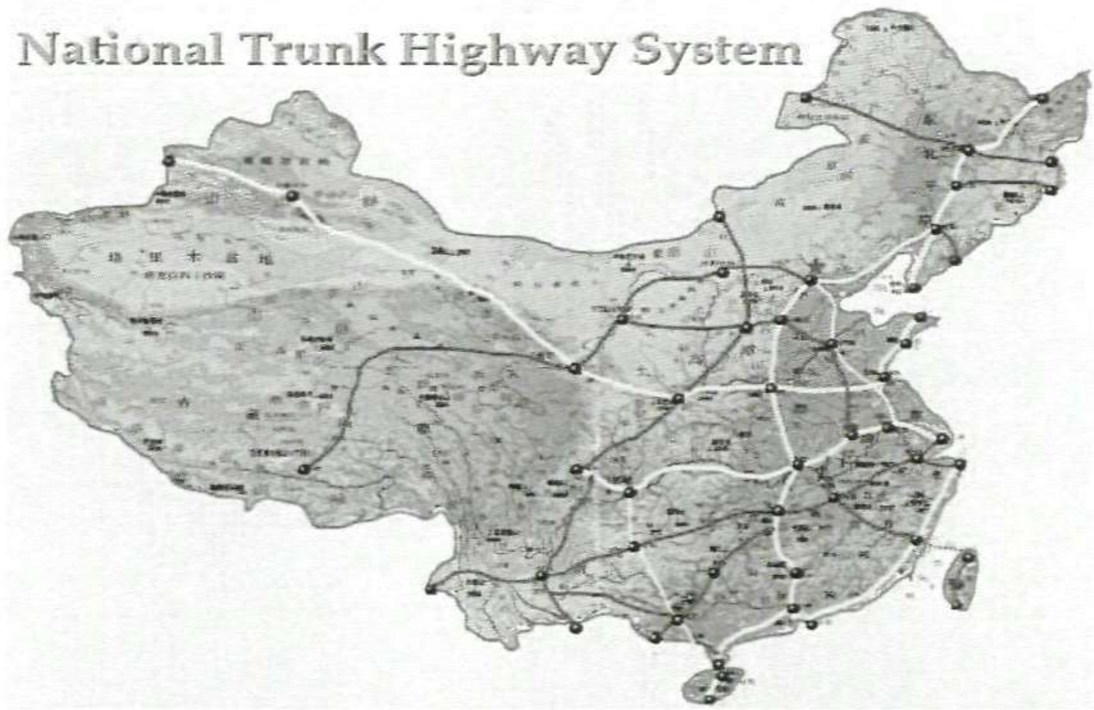
	A									
	B1 (0.6370)				B2 (0.2583)		B3 (0.1047)			
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	0.96									
M2	0.74									
M3	0.82									
M4		0.63								
M5		0.38								
M6		0.82								
M7			0.24							
M8			0.14							
M9			0.83							
M10			0.78							
M11			0.19							
M12				0.3						
M13				0.18						
M14					0.5					
M15						0.33				
M16							0.42			
M17							0.74			
M18								0.18		
M19									0.72	
M20									0.47	
M21										0.26
M22										0.65
M23										0.49
M SUM	2.52	1.83	2.18	0.48	0.5	0.33	1.16	0.18	1.19	1.4
M*D or C	0.802	0.291	0.232	0.026	0.055	0.037	0.043	0.004	0.015	0.095
									Final Sum	1.600

C7 Hafei Motor Co. Ltd

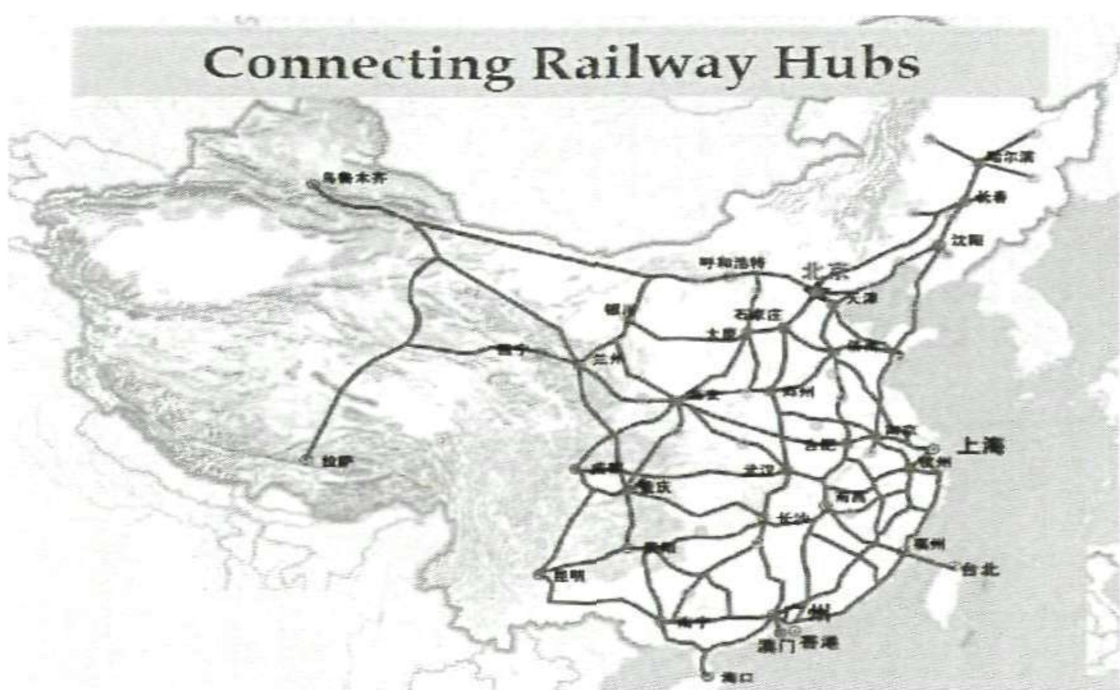
Supply chain performance weighted index, empirical data and final weightiness

A										
	B1 (0.6370)				B2 (0.2583)			B3 (0.1047)		
	C1 (0.75)	C2 (0.25)			C3	C4	C5	C6	C7	C8
	D1	D2	D3	D4						
	0.319	0.159	0.106	0.053	0.111	0.111	0.037	0.024	0.013	0.068
M1	0.95									
M2	0.64									
M3	0.79									
M4		0.61								
M5		0.23								
M6		0.81								
M7			0.6							
M8			0.09							
M9			0.09							
M10			0.06							
M11			0.02							
M12				0.71						
M13				0.7						
M14					0.55					
M15						0.29				
M16							0.35			
M17							0.54			
M18								0.16		
M19									0.66	
M20									0.33	
M21										0.18
M22										0.48
M23										0.45
M SUM	2.38	1.65	0.86	1.41	0.55	0.29	0.89	0.16	0.99	1.11
M*D or C	0.758	0.263	0.091	0.075	0.061	0.032	0.033	0.004	0.013	0.075
									Final Sum	1.405

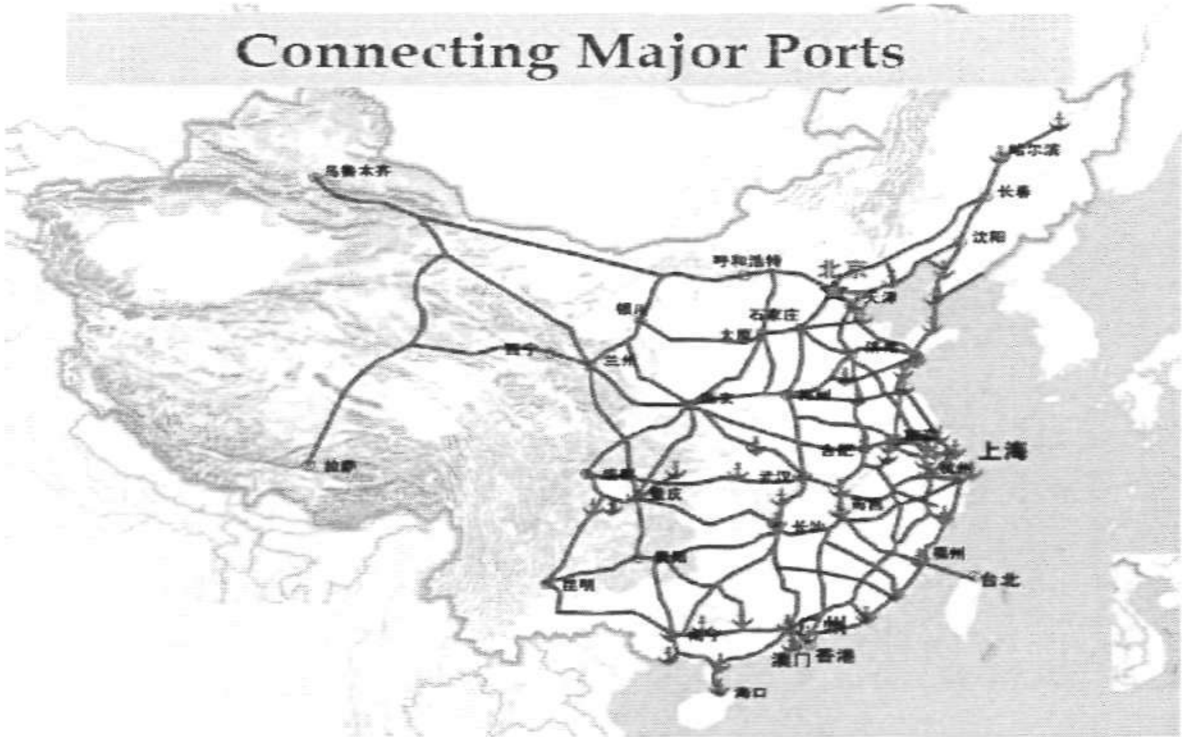
Appendix 14: National highway transportation network



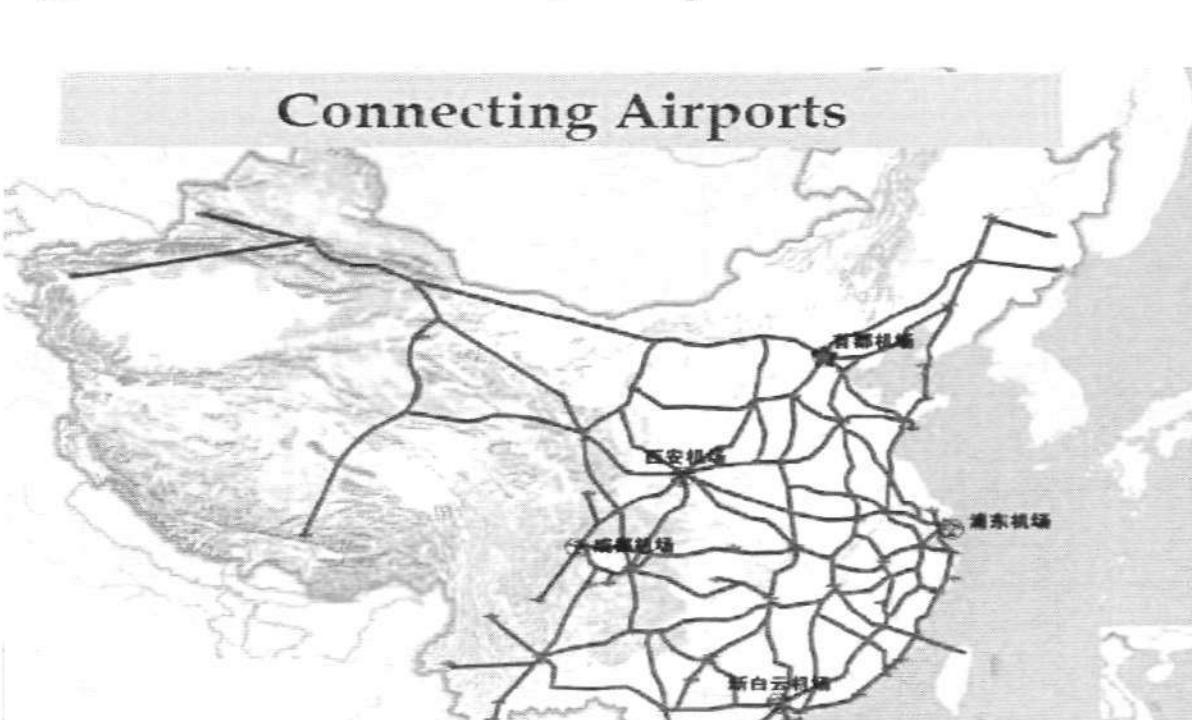
Appendix 15: National railway transportation network



Appendix 16: National major ports network



Appendix 17: National major airports network



Reference

Aberdeen Group (1996). "Advanced Planning Engine Technologies: Can Capital Generating Technology Change the Face of Manufacturing?." "White Paper.".

Aervitz, I. (2008). "Chinese cherish their Chery " Asia times **Available on: http://www.atimes.com**.

Agarwal, A. and R. Shankar (2002). "Analyzing alternatives for improvement in supply chain performance." Work study **Vol. 51**(No. 1): PP. 32-37.

Agarwala, A., R. Shankara, et al. (2006). "Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach " European Journal of Operational Research **Vol 173**(Issue 1): PP. 211-225

AIB (2006). AIB Business-Stock Turnover Ratio Wizard. Allied Irish Banks, http://www.aib.ie/servlet/ContentServer/AIB_BusinessPortal.

Akash, B. A., R. Mamlook, et al. (1999). "Multi-criteria selection of electric power plants using analytical hierarchy process " Electric Power Systems Research **Vol. 52**(Issue 1): PP. 29-35

Ally, R. (2008). "Chinese auto parts exporters challenged by experts to raise technical contents." Global auto sources-Connecting Automotive Buyers and Suppliers **Available on Gasgoo.com**.

Alphonce, C. B. (1997). "Application of the analytic hierarchy process in agriculture in developing countries" Agricultural Systems **Vol. 53**(Issue 1): PP. 97-112

Arabia, S. (2006). "Record oil price sets the scene for $200 next year" Available on: http://www.ameinfo.com/90848.html.

Aslani, G., S. H. Momeni-Masuleh, et al. (2009). "Bank efficiency evaluation using a neural network-DEA method." Iranian Journal of Mathematical Sciences and Informatics **Vol. 4**(No. 2): PP. 33-48.

Automotive Industry Report (2008). 2006-2007 Research Report on China Automotive Market The Automotive Research Association of China.

Baatz, E. B. (1995). "CIO 100-a best practices: the chain gang." CIO **Vol. 8** (No.19): PP.46-52.

Bai, X. M. and I. Hidefumi (2002). "Towards sustainable urban water resource management: a case study in Tianjin, China." Sustainable Development **Vol. 9**: PP. 24-35.

Bai, Y. and S. Chen (2009). "Chinese automotive marketing strategy and development." China

Collective Economy **Vol. 30**: PP. 35-43.

Banwet, J. a. D. K. and S. G. Deshmukh (2008). "Evaluating performance of national R&D organizations using integrated DEA-AHP technique." International Journal of Productivity and Performance Management **Vol. 57**(No. 5): PP. 370-388.

BBC News (2010). "China car sales 'overtook the US' in 2009" Available on: http://news.bbc.co.uk/2/hi/8451887.stm.

Beamon, B. M. (1996). "Performance measures in supply chain management " Proceedings of the 1996 Conference on Agile and Intelligent Manufacturing Systems **Rensselaer Polytechnic Institute, Troy, New York , NY**.

Beamon, B. M. (1999). "Measuring supply chain performance." International Journal of Operations and Production Management **Vol. 19**(No. 3,): pp. 275-292,.

Benbasat, I., D. K. Goldstein, et al. (1987). "The Case Research Strategy in Studies of Information Systems." Management Information Systems Research Center, University of Minnesota. **Vol. 11** (No. 3): PP. 369-386

Bi, M. (2007). "SAIC and Yuejin Auto merger creates Chinese car colossus " Window of China, Available on: www.chinaview.cn

Bian, L., A. Liu, et al. (2007). "The Relationship Among Current Asset Operation, Payoff Ability and Growth Ability: An Empirical Study on Chinese Agriculture-listed Company." Chinese Agricultural Science Bulletin **Vol. 23**(No. 9).

Bigliardi, B. and E. Bottani (2010). "Performance measurement in the food supply chain: a balanced scorecard approach." Facilities **Vol. 28**(No. 5/6): PP. 249-260.

Blackburn, J. D. (1992). "Time-based competition: white-collar activities." Business Horizons: http://www.findarticles.com.

Blair, A. R., Nachtmann.R, et al. (2001). "Forecasting the resurgence of the US economy in : an expert judgement approach." Socio-Econ Plan Sci **Vol. 36** PP. 71-91.

Bogdan, R. C. and S. K. Biklen, Eds. (1998). Qualitative research for education: An introduction to theory and methods, Boston: Allyn and Bacon.

Borg, W. R., M. D. Gall, et al. (1989). Educational Research: An Introduction (5th Edition) New York, Longman.

Bourne, M., J. Mills, et al. (2000). "Designing, implementing and updating performance measurement systems." International Journal of Operations and Production Management **Vol. 20**:

PP. 754-771.

Bowersox, D. J., D. J. Closs, et al., Eds. (2002). Supply chain logistics management, Michigan State University, Brent Gordon.

Bradsher, K. (2007). "Shanghai Automotive Industry Corporation To Spend $255 Million On Technology Center." Available at the New York times: http://www.nytimes.com/.

Bradsher, K. (2008). "China makes a move into high-value exports." International Herald Tribune.

Brewer, P. C. and S. Thomas W (2000). "Using The Balanced Scorecard To Measure Supply Chain Performance " Journal of Business Logistics **Vol.21**(No. 1): PP. 75-93.

Brown, M. (1996). keeping score: using the right metics to drive world class performance, Quality Resources, New York, NY.

Bruce, H. (1997). "Demand chain management-the future paradigm for the 21st century." 1997 Conference Proceedings, American production and control society.

Bruce, M., L. Daly, et al. (2004). "Lean or agile: A solution for supply chain management in the textiles and clothing industry?" International Journal of Operations & Production Management **Vol. 24** (No. 2): PP. 151-170

Bryman, A. (2001). Social Research Methods [Paperback], Oxford University Press, USA

Business Knowledge Center (2008). "The Balanced Scorecard." Available on Business Knowledge Center: www. netmba.com.

Cai, H. and Y. Shi (2007). "Discussing the Relations between ERP and ERP II " Manufacturing information engineering of China **Vol. 15** (PP.121-123).

Carr, A. S. and J. N. Pearson (1999). "Strategically managed buyer-supplier relationships and performance outcomes." Journal of Operations Management **Vol. 17** (No. 5): PP. 497-519.

Castillo, J. J. (2009). "Non-probability Sampling. Retrieved [Date of Retrieval] from Experiment Resources." Available on: http://www.experiment-resources.com/non-probability-sampling.html.

Cavana, R., B. L. Delahaye, et al. (2001). Applied Business Research: Qualitative and Quantitative Methods John Wiley and Sons Australia Ltd, Milton, Queensland.

Cavinato, J. L. (1982). Transportation Logistics Dictionary The Traffic Service Corporation

Cavinato, J. L. (1992). "A Total Cost/Value Model for Supply Chain Competitiveness" Journal of Business Logistics **Vol. 13**: PP. 285-301.

Center for Information Industry Development (CCID) (2008). "2007-2008 Annual Report on China's Automotive Electronics Market." CCID Consulting Journal of China.

Chan, F. T. S., H. C. W. Lau, et al. (2006). "An AHP approach in benchmarking logistics performance of the postal industry." Benchmarking: An International Journal **Vol. 13**(No. 6): PP. 636-661.

Chan, F. T. S. and H. J. Qi (2003). "Feasibility of performance measurement system for supply chain : a process-based approach and measures." Integrated Manufacturing Systems **Vol. 4** (No. 3): pp179-190.

Chan, F. T. S. and H. J. Qi (2003). "Feasibility of performance measurement system for supply chain: a process-based approach and measures " Integrated Manufacturing Systems **Vol. 14**(No. 3): PP. 179-190

Chan, F. T. S. and H. J. Qi (2003). "An innovative performance measurement method for supply chain management " Supply Chain Management: An International Journal **Vol. 8** (No. 3): pp. 209 - 223

Chang'an Auto website (2007). "ChangAn Auto Uses Experienced Consultants to Build Comprehensive IT Infrastructure." Available on: ww.changan.com.cn.

Chao, F. Q., H. Wang, et al. (2009). "Analysis on Support Environment for Reorganized China Automotive Industry " Journal of Wuhan University of Technology (Information and management Engineering) **Vol. 5**: PP. 133-137.

Chao, L., P. Xue, et al. (2007). "Performance Evaluation of Shanghai Automobile Corporation Financial Risk After Reformation." Journal of Harbin University Of Commerce (Social Science Edition) **Vol. 3**: PP. 407-417.

Charnes, A., W. W. Cooper, et al. (1978). "Measuring the efficiency of decision making units." European Journal of Operational Research **Vol. 2**: PP. 429-44.

Chedid, R. B. (2002). "Policy development for solar water heaters: the case of Lebanon." Energy Convers Manage **Vol. 43** PP. 77-86.

Chen, F. and X. Liu (2006). "Risk Analysis on The Investment in Auto Sector " Shanghai Auto **Vol. 12**: PP.123-130.

Chen, X. and W. Yang (2006). "Analysis for inventory optimum management of package enterprise "Packaging Engineering **Vol. 5**: PP. 213-215.

Chen, Z., P. Shi, et al. (2005). "China's WTO accession impacts on domestic automobile industry—a rudimental approach from the view of scale economy." Team Project of International Trade.

Chen, Z. and Q. Yun. (2006). "Research on Countermeasures for Automobile Logistics in China." Storage, Transportation and Preservation of Commodities **Vol. 6**: PP. 234-235.

Chery Website (2006). "Chery News release." Available on: www.chery.cn/.

Chia, A., M. Goh, et al. (2009). "Performance measurement in supply chain entities: balanced scorecard perspective." Benchmarking: An International Journal **Vol. 16**(No. 5): PP. 605-620.

China Automotive News (2008). "Many Chinese automakers facing overcapacity." Available at China automotive news: www.gasgoo.com/auto-news/.

China Car Times (2008). "Roewe Sales, not what we were lead to believe?" Available on: http://www.chinacartimes.com.

China economic review (2007). "China rail container joint venture." Available on: http://www.chinaeconomicreview.com.

Chow, G., T. D. Heaver, et al. (1994). "Logistics Performance: Definition and Measurement." International Journal of Physical Distribution and Logistics Management **Vol. 24** (No. 1): PP. 17-28.

Chow, W. S., C. N. Madu, et al. (2008). "Supply chain management in the US and Taiwan-An empirical study." the international Journal of Management Science **Vol. 36**: PP. 665-679.

Christopher, M. (1992). Logistics and supply chain management Pitman Publishing , London.

Christopher, M., Ed. (1998). Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service (hardback) Financial Times : Pitman Publishing. London.

Christopher, M. and D. Towill (2001). "An Integrated Model for the Design of Agile Supply Chains." International Journal of Physical Distribution & Logistics management **Vol. 31**(No. 4): PP. 235-246.

Chun-mei, L. (2006). "The Application of Logistics Standardization in China." Commercial Research **Vol. 5**: PP. 15-23.

Clark, L. S. (2004). "The Journey from Post-Positivist to Constructivist Methods." Media, Home, and Family . New York: Routledge.: PP. 19-34.

Company's Website News (2007). "BMW Group's development in China." Available on: http://www.bmw.com.cn.

Cooney, S. (2006). "China's Impact on the U.S. Automotive Industry." Congressional Research Service , The Library of Congress.

Cooper, D. and P. Schindler (1998). Business Research Methods. , 6th Edition. New York. McGraw Hill.

Cox, J. F. and J. H. Blackstone (2004). APICS Dictionary (Paperback) APICS Educational Society for Resource Manage.

Creswell, J. W. (1994). Research design: Qualitative and quantitative approaches, London, UK: Sage.

Creswell, J. W. (1998). Qualitative inquiry and research design: Choosing among five traditions, Thousand Oaks, CA: SAGE Publications.

CSCMP (2006). "Council of Supply Chain Management Professionals." http://www.cscmp.org.

Dai, Y. (2008). "Third Party Logistics Industry's Comparison & Feature Analysis " Logistics Management
Vol. 3: PP. 237-245.

Darke, P., G. Shanks, et al. (1998). "Successfully completing case study research: combining rigor, relevance and pragmatism." Information Systems Journal **Vol 8**: PP. 273-289.

Davis, T. (1993). "Effective Supply Chain Management." Operations Management and Research, MIT Sloan Management Review **Vol. 34**, (No. 4,): PP. 35-46.

Deng, J. (1985). "Special issue of grey system approach." Fuzzy Math **Vol.5**(No. 2).

Deng, Q. and S. Tang (2007). "The Study on Appraisal of the Performance of Supply Chain Partners " Commercial Research **Vol. 12**: PP. 116-123.

Denscombe, M. (1998). The Good Research Guide: For Small Scale Research Projects, Buckingham: Open University Press.

Denzin, N. K. and Y. S. Lincoln (2000). The handbook of qualitative research (2nd ed), Thousand Oaks, CA: Sage.

Dey, P. K., S. Hariharan, et al. (2006). "Measuring the operational performance of intensive care units using the analytic hierarchy process approach." International Journal of Operations and Production Management **Vol 26**(No. 8): PP. 849-865 (17).

Dick, B. (2002). "Postgraduate programs using action research." The Learning Organization **Vol. 9**(Issue 4): PP. 159-170.

Ding, L., N. Cui, et al. (2006). "How to Optimize the Inventory in Automobile Spare Parts Service Based on Classification Management." Logistics Technology **Vol. 3**: PP.67-79.

Dixon, J. R., A. J. Nanni, et al. (1990). The New Performance Challenge: Measuring Operations for World Calls Competition Dow-Jones Irwin, Homewood, IL.

Dongfeng Annual Results Announcement (2008). "Dongfeng Motor Business Review." Available at: http://www.dfmc.com.cn.

Duguay, C. R., S. Landry, et al. (1997). "From mass production to flexible/agile production" International Journal of Operations & Production Management , **Vol. 17**(No. 12): PP. 1183-1195.

Easterby-Smith, M., R. Thorpe, et al., Eds. (2002). Management Research: An Introduction. London, Sage Publications.

Eisenstein, P. (2002). "Driven by demand." Professional Engineering **Vol. 15** (No.9): PP.32.

Erdoğmuşa, Ş., H. Arasb, et al. (2006). "Evaluation of alternative fuels for residential heating in Turkey using analytic network process (ANP) with group decision-making" Renewable and Sustainable Energy Reviews **Vol. 10**(No. 3): PP. 269-279

Ettlie, J. E. and E. M. Reza (1992). "Organizational integration and process innovation. ." Academy of Management Journal **Vol. 35** (No. 4): PP. 795-828.

Fahmy, H. M. A. (2001). "Reliability evaluation in distributed computing environments using the AHP " Computer Networks **Vol. 36**(Issues 5-6): PP. 597-615

Fan, C. and N. P. Xin (2005). "Summary of Research on Logistics Performance Evaluation " Logistics Technology **Vol. 9**: PP. 103-112.

Fang, C. and S. Gong (2008). "Research on how to develop supply chain human resources in automobile industry " Logistics and Material Handing: PP.11-23.

Fang, C., S. Gong, et al. (2006). "Conforming China automobile logistics supply with forth party logistics " Special Zone Economy **Vol. 5**: PP. 233-238.

Fang, Z., Y. Li, et al. (2007). "Performance analysis of supply chain based on two typical production models." Science Research Management **Vol. 1**: PP. 76-82.

FAW New (2008). "Research and development introduction." Available on: www.faw.com.cn.

First Automotive Works Website (2008). "First automotive works-Research and development news." Available on: http://www.faw.com/webcontent/news.jsp.

Fitzgerald, L. (1991). Performance measurement in service businesses Chartered Institute of Management Accountants. London.

Forman, E. H. (1990). "Random Indices for Incomplete Pairwise Comparison Matrices." European Journal of Operational Research **Vol. 48**(No. 1): PP. 153-155.

Forman, E. H. (1996). Manuscript: Decision by Objectives Expert Choice, Pittsburg, PA.

Frei, F. X. and P. T. Harker (1999). "Measuring aggregate process performance using AHP." European Journal of Operational Research **Vol. 116** PP. 436-442.

Fu, Y. and X. Zhang (2008). "Development Trend of China Auto Industry in the New Century-competition in auto-finance services." The banker **Vol. 15**.

Fu, Y. W., X. Ru, et al. (2009). "China's Vehicle Industry Sees Chances Amid Crisis " Available on: www.chinadaily.com.cn.

Galliers, R. D. and F. F. Land (1987). "Choosing Appropriate Information Systems Research Methodologies." Communications of the ACM **Vol. 30**(No. 11).

Ge, Y. (2008). "Employee Satisfaction Supervision and Its Practical Application in Management Decision." Economy and Management **Vol. 19**: PP. 23-25.

Gerson, K. and R. Horowitz (2002). Observational and interviewing: options and choices in qualitative research, Qualitative Research in Action, Sage Publications, .

Ghalayini, A. M. and J. S. Noble (1996). "The changing basis of performance measurement." International Journal of Operations & Production Management **Vol: 16**: PP. 63-80.

Ghalayini, A. M. and J. S. Noble (1996). "The changing basis of performance measurement." International Journal of Operations and Production Management, **Vol. 16**(PP. 63-80).

Ghauri, P. and K. Gronhaug (2002). Research Methods in Business Studies, Prentice Hall, London.

Gillham, B. (2000). "Case study research methods." Real world research.

Globerson, S. (1985). "Issues in developing a performance criteria system for an organization" International Journal of Production Research **Vol. 23**(No. 4): PP. 639-46.

Gong, Z. and Y. Wu (2008). "BMW tie-up may add plant." China business daily.

GSCF (2006). "Global Supply Chain Forum " http://fisher.osu.edu/centers/scm.

Gua, L. and X. Hao (2007). "Integration study on supply chain cost." Marketing Modernization **Vol. 9**: PP. 4-12.

Gua, L. j. (2005). "Theoretical Foundations and Methods Study of Cost Management in Supply Chain." Accounting Research **Vol. 4**: PP. 101-112.

Gunasekaran, A., C. Patel, et al. (2004). "A framework for supply chain performance measurement." Int. J. Production Economics **Vo. 87**: PP. 333-347.

Gunasekaran, A., C. Patel, et al. (2001). "Performance measures and metric in a supply chain environment." International Journal of Operations & Production Mnagement **Vol. 21**(No. 1/2): PP. 71-87.

Gunther, M. (2006). "The Green Machine." Fortune Magazine.

Guo, G. and L. Qing (2005). "Optimization of supply chain management in Dongfeng Motor Corporation." Logistics Technology **Vol. 11**: PP.82-84.

Guo, P. and H. Tanaka (1998). "Extended fuzzy DEA." Proceedings of the 3rd Asian Fuzzy system symposium: PP.517-521.

Guo, R., Y. Miao, et al. (2007). "The Global Supply Chain Event for China" Available on: www.supplychain.cn.

Han, X. (2009). "Research on structural Mode of China Auto Marketing System and Sales Market " Auto Industry Research **Vol. 8**: PP.101-106.

He, Y. and X. M. Zhang (2004). "Investigating the profit growth rate of the losing enterprises " Finance and Accounting Monthly **Vol. 2**: PP. 4-12.

Henry, C. W., K. M. L. Carman, et al. (2006). "M-commerce to support the implementation of a responsive supply chain network." Supply Chain Management: An International Journal **Vol. 11** Page: 169 - 178.

Hoek, R. I. v. (1999). "From reversed logistics to green supply chain." Supply chain Management **Vol. 4** (No. 3): PP. 129-134.

Hoek, R. I. v. (2000). "The thesis of leagility revisited " International Journal of Agile Management Systems **Vol: 2**(No. 3): PP:196 - 201

Hoekstra, S. and J. Romme (1992). " Integral Logistics Strictures: Developing Customer-orientated Goods Flow." New York: Simon and Schuster.

Holweg, M. and J. Miemczyk (2002). "Logistics in the "three-day car" age-Assessing the responsiveness of vehicle distribution logistics in the UK " International Journal of Physical Distribution and Logistics Management **Vol. 32**(No.10): PP. 829-850.

Holweg, M. and F. K. Pil, Eds. (2004). The Second Century: Reconnecting Customer and Value Chain through Build-to-Order: Moving Beyond Mass and Lean Production in the Auto Industry, MIT Press, Cambridge, MA.

Hou, l. and D. Zhu (2006). "Standardization Promotes the Development of Logistics Equipment Industry " Logistics and Material Handling **Vol.12**: PP.12-13.

Hu, X. D. and L. Zhang (2007). "Staff Training and Development in Open and Distance Learning." MODERN MANAGEMENT SCIENCE **Vol. 1**: PP. 276-279.

Huang, G. (2006). "The execution of SAP IS-AUTO system in Shanghai Automotive Industry Coperation." Shanghai Auto **Vol 3**: PP. 3-5.

Huang, L. and y. Lin (2005). "Comparative analysis on traditional procurement and e-procurement strategy of supply chain." Journal of systems science and systems engineering **Vol. 4**: PP. 51-55.

Huang, X. (2007). "Develop China's Automotive Industry by Proper Guidance and Bringing Its Own Advantages into Full Play." Shanghai Motor **Vol. 7**: PP. 7-11.

Huang, Y. P. and H. J. Zhang (2006). "An Approach of Logistics Cost Control for Guo Mei retailer." System Engineering **Vol. 1**: PP. 69-71.

Hui, W. (2009). Research on Development of Automotive Spare Part Industry in China. 2009 International Conference on Auto Industry Innovation

Huo, J., X. Ma, et al. (2002). "Construction of Integrated Supply Chain Performance Measurement System." Journal of Tongji University (Natural Science) **Vol. 4**: PP. 121-135.

Hussey, J. and R. Hussey (1997). Business Research: a Practical Guide for Undergraduate and Postgraduate Students, Hampshire: Palgrave.

ICAS (1993). "Measurement – The Total Picture, ."The Institute of Chartered Accounts of Scotland.

Industrial standards (2004). "Regulations of Transportation Service for Passenger Vehicle." Available on : http://www.bjstandard.com/standard/.

Investor Words (2008). "Net profit margin definition." Available on the: http://www.investorwords.com.

Investorworld (2006). "Investor Guide.com - Asset Turnover" http://www.investorwords.com/291/asset_turnover.html.

J.D. Power and Associates (2008). J.D.Power Business Center Press: 2007 China Sales Satisfaction Index Study (SSI) Available on: http://businesscenter.jdpower.com/news/pressrelease.

Jaber, O. J. and S. M. Mohsen (2001). "Evaluation of non-conventional water resources supply in Jordan." Desalination **Vol. 136**(No. 1-3): PP. 83-92

Jia, W. and X. Luan (2007). "Considerations on How to Develop Third Party Logistics in China " China Market **Vol. 19**: PP. 15-21.

Jiang, C. and X. Wu (2006). "Reducing Logistic Cost, Creating "Two-Win" in Car Supply Chains " Value Engineering: PP. 69-82.

Jiang, C. C. and L. S. Han (2008). "Reducing Logistic Cost to Creating "Two-Win" in Car Supply Chains." VALUE ENGINEERING **Vol 24 (4)**: PP. 222-259.

Jiang, D. s., H. Guo, et al. (2008). " Reflections on Reform of Tax Policy In the Automotive Industry." Journal of Shangdong Institute of Business and Technology **Vol. 5**(PP. 85-91).

Jin, Y. F. and Q. Bai (2007). "Research on Models of Training in Enterprises in China " Continue Education Research **Vol 8**: PP. 147-149.

Jing, H. and B. Waller (2008). "Current State of Auto Industry." Guodu security securies centre **Financial Executive.**

Johansson, H., P. McHugh, et al. (1993). Business process reengineering: breakpoint strategies for market dominance, John Wiley.

Johnes, J. (2006). "Data envelopment analysis and its application to the measurement of efficiency in higher education." Economics of Education Review **Vol. 5**: PP. 273-88.

Jonsson, P. and M. Lesshammar (1999). "Evaluation and improvement of manufacturing performance measurement systems - the role of OEE." International Journal of Operations and Production Management **Vol. 2**: PP. 283 - 296

Jorgensen, B. (2005). " The "Greening" of The Supply Chain." Electronic Business **Vol. 31** (6): PP. 29-30.

Joseph, K. E. and D. Chang-jun (2009). "The Impacts of Human Resource Management Practices on the Performance of Enterprises in Abidjan." JOURNAL OF DONGHUA UNIVERSITY(ENGLISH EDITION) **Vol. 26 (1)**: PP. 71-79.

Jun-jie, Z. and H. Ning (2007). " Elementary Discussion on Status of Logistics Standardization and Its Countermeasures." Communications Standardization: PP. 99-101.

Jun, X. (1990). "A grey system method applied to forecasting of lake water quality." Grey System **Vol. 2**(No. 3): PP. 257-266.

Kaplan, R. S. and D. P. Norton (1992). "The balanced scorecard-measures that drive performance." Harvard Business Review **Vol. 70** PP.71-79.

Kaplan, R. S. and D. P. Norton (1992). The Balanced Scorecard: Measures That Drive Performance (HBR OnPoint Enhanced Edition) Harvard Business Review, January -February, PP, 71-9.

Kaplan, R. S. and D. P. Norton (1996). The Balanced Scorecard: Translating Strategy into Action (Hardcover) Harvard Business School Press

Karmarkar, U. (1989). "Getting control of just-in-time." Harvard Business Review **Vol. 67** (No. 5): PP. 122-131.

Kauffman (2006). Foundation Kauffman-Business Glossary, Ewing Marion Kauffman Foundationt--the Entrepreneur 's trust guide to high growth , http://eventuring.kauffman.org.

Keebler, J. S. and R. E. Plank (2009). "Logistics performance measurement in the supply chain: a benchmark." Benchmarking: An International Journal **Vol. 16**(No. 6): PP. 785-798.

Kengpol, A. (2002). "The decision support system to select the investment in a new distribution centre using the analytic hierarchy process, a capital investment model and a transportation model." Journal KMITNB **Vol. 12**(No. 2): PP.31-37.

Kuhn, J. (2006). "Evolution of a worldwide production network." Journal of Manufacturing Technology Management **Vol. 17**: PP. 1099 - 1116.

Kumar, A., L. Ozdamar, et al. (2005). "Procurement Performance Measurement System in the Health Care Industry." International Journal of Health Care Quality Assurance **Vol. 18** (No. 2): PP. 152-166.

Kumar, V., K. A. Fantazy, et al. (2006). "Implementation and management framework for supply chain felxibility." Journal of Enterprise Information Management **Vol. 19**(No. 3): PP. 1741-0398.

Kuo, R. J., S. C. Chi, et al. (2002). "A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network " Computers in Industry **Vol. 47**(Issue 2): PP 199-214

Kwak, N. K. and C. Lee (1998). "A multicriteria decision-making approach to university resource allocations and information infrastructure planning." European Journal of Operational Research **Vol. 110** PP. 234-242.

KWAN, C. (2005). "Chinese Automobile Industry Facing Overcapacity - Japanese Automakers Required to Change Their Strategy " China in Transition.

Lai, V. S., B. K. Wong, et al. (2002). "Group decision making in a multiple criteria environment: A case using the AHP in software selection " European Journal of Operational Research **Vol. 137**(No.1): PP. 134-144

Lambert, D. M., Ed. (2008). Supply chain management: processes, partnerships, performance, Supply Chain Management Institute.

Lau, H. C. W., C. K. M. Lee, et al. (2006). "M-commerce to support the implementation of a responsive supply chain network." Supply Chain Management: An International Journal **Vol. 11**(No. 2): PP.169-178.

Lee, A. S. (1989). "A Scientific Methodology for MIS Case Studies." MIS Quarterly **Vol 13**(Issue 1): PP. 33-52. .

Lee, C. W. and N. K. Kwak (1999). "Information resource planning for a health-care system using an AHP-based goal programming method " Journal of The Operational research society **Vol. 50** (No. 12): PP.1191-1198

Lee, H., W. Kwak, et al. (1995). "Developing a business performance evaluation system: An analytic hierarchical model." Engineering Economist, Available on: http://www.findarticles.com/p/articles.

Lee, H. L. and C. Billington (1992). "Managing supply chain inventory: pitfalls and opportunities." Sloan Management Review **Vol. 33**(No. 3): PP. 65-73.

Leedy, P. and J. Ormrod (2001). Practical research: Planning and design (7th ed), Upper Saddle River, NJ: Merrill Prentice Hall. Thousand Oaks: SAGE Publications.

Leedy, P. D. and J. Ormrod (2001). Practical research: Planning and design (7th ed), Upper Saddle River, NJ: Merrill Prentice Hall. Thousand Oaks: SAGE Publications.

Leedy, P. D. and J. E. Ormrod (2004). Practical Research: Planning and Design (Eight Edition)), Allyn & Bacon.

Lei, L. (2006). "China to be world's third largest auto-manufacturer." People's daily **Vol. 12**.

Leong, G. K., D. L. Snyder, et al. (1990). "Research in the Process and Content of Manufacturing Strategy." International Journal of Management Science (OMEGA) **Vol. 18**(No. 3): PP. 283-97.

Levin, D. M., Ed. (1988). The opening of vision: Nihilism and the postmodern situation. London, Routledge.

Li, D. (2003). "Application of SPC in Quality Management Model ASP R/3." Manufacturing Automation **Vol. 21**: PP. 4-12.

Li, J. and J. Lin (2008). "Development of Automobile Finance Corporation after China's Entering WTO " Journal of Wuhan University of Technology (Information and Management Engineering): PP.189-192.

Li, J. and Y. B. Shi (2009). "On Restructuring Strategy of Chinese Independent Brand of Automobile Enterprise under Financial Crisis " Business Economy **Vol 14**: PP. 221-234.

Li, J., H. Wang, et al. (2007). "Research on the supply chain performance appraisal index system." Journal of HuBei University of Engineering **Vol. 3**.

Li, Y. M. (2007). "Automotive Industrial Development." 2007 Annual Conference Of Chinese Automotive Logistics Industry--Invest in Anhui province

Liang, L. (2005). "Supply Chain Revolution in IT Times " Shanghai Auto **Vol. 5**: PP. 25-27.

Lin, C. T. and P. F. Hsu (2003). "Adopting an analytic hierarchy process to select internet advertising networks." Marketing Intelligence & Planning **Vol. 21**(No. 3): PP. 183-191.

Lin, F. and M. J. Shaw (1998). "Reengineering the order fulfillment process in supply chain networks." The International Journal of Flexible Manufacturing Systems **Vol. 10** (No. 3): PP.197-229.

Lin, Z. and H. Yao (2006). "Research and Exploring for Standardization of Automobile Logistics " Journal of Shanghai Dianji University **Vol. 6**: PP. 144-156.

Lin, z. y. (2007). "Research and Exploring for Standardization of Automobile Logistics." Journal of Shanghai Dianji University **Vol. 13**: PP. 31-33.

Liu, Q. L. (2009). " Impact of Fuel Consumption Tax Reform on Chinese Automotive Industry." Energy of China **Vol. 3**: PP. 121-123.

Liu, R. M. and Y. Z. Yan (2006). "A Study of Application of Human Resource Accounting " Journal of Shanxi Finance and Tax college **Vol. 3**: PP. 56-67.

Liu, X., L. Qiu, et al. (2007). "Spare parts inventory management in special steel enterprise." Computer Integrated Manufacturing Systems **Vol. 9**: PP.78-81.

Lo, C. W. and S. W. Leung (2000). "Environmental agency and public opinion in Guangzhou: the limits of a popular approach to environmental governance." The China Quarterly **Vol. 163**: PP. 677-704.

Logistics Press (2008). "Inventory Management for the Supply Chain." Available on: http://www.leanlogistics.com.

Lohman, C., L. Fortuin, et al. (2004). "Designing a performance measurement system: A case study " European Journal of Operational Research **Vol. 156**(Issue 2): PP. 267-286

Lohman, C., L. Fortuin, et al. (2004). "Designing a performance measurement system: A case study." European Journal of Operational Research **Vol. 156**: PP. 267-286.

Lohman, C., L. Fortuin, et al. (2004). "Designing a performance measurement system: A case study." European Journal of Operational Research **Vol. 156**: PP. 267-286.

Londe, B. J. L. and J. M. Masters (1994). "Emerging logistics strategies: blue print for the next century." International Journal of Physical Distribution & Logistics Management **Vol. 24** (No.7): PP.35-47.

Lu, W., F. Xia, et al. (2006). "Understanding the Concept of "Third Party Logistics" and its Application " Industrial Engineering and Management **Vol. 6**: PP. 222-259.

Lummus, R. R. and R. J. Vokurka (1999). "Defining supply chain management: a historical perspective and practical guidelines." Industry Management & Data System **Vol. 99** (No. 1): PP. 11-17.

Luo, W. P. (2004). Global cases in supply chain management, Tinghua University Press.

Lynch, R. L. and K. F. Cross (1991). Measure Up – the Essential Guide to Measuring Business Performance., Mandarin, London.

Lyons, A., J. Coleman, et al. (2004). "Performance observation and analysis of an information re-engineered supply chain: a case study of an automotive firm." Industry Management and Data System **Vol. 104**(No. 8): PP. 658-666.

Ma, S. and S. Wei (2006). "A Diagnostic Model of SC Logistics Capability Based on Quick Response." Logistics Technology **Vol. 4**: PP. 13-24.

Mann, Y. (2008). "Brief Analysis of China Commercial Vehicle Import and Export Market in the First Quarter of " Commercial Vehicle **Vol. 16**: PP. 2-4.

Mao, J., Z. Zhang, et al. (2008). "The automotive supply chain organization: Global Trends and Perspectives." Industrial Technology and Economy **Vol. 22**(Issue 2): PP. 89-90.

Martin, C. (2005). Logistics and supply chain management-Creating value-adding networks. Great Britain, Pearson Education Limited, Great Britain.

Maskell, B. H. (1991). "Performance measurement for world class manufacturing. A model for American companies, ." Productivity Press, Cambridge, MA, .

Maskell, B. H. (1991). Performance Measurement for World Class Manufacturing: A Model for American Companies (Corporate Leadership) (Hardcover) Productivity Press

McDaniel, C. and R. H. Gates (1999). Contemporary Marketing Research 4th edition. Cincinnati: South-Western College Publishing.

McDaniel, C. and R. H. Gates (1999). Contemporary marketing research (Hardcover) South-Western College Publishing.

McMillan, J. H. and S. Schumacher (1993). Research in Education: A Conceptual Introduction (3rd Edition) New York: Harper Collins College Publisher.

Meade, L. and J. Sarkis (2002). "A conceptual model for selecting and evaluating third-party reverse logistics providers " Supply Chain Management: An international Journal **Vol. 7** (Number 5): PP. 283-295

Mei, Y. H. (2008). "Independent Innovation and Chinese Automobile Industry." Science and Technology Industry of China **Vol. 12**: PP.15-18.

Miles, M. B. and A. M. Huberman (1994). Qualitative data analysis (2nd Edition), Thousand Oaks, CA: Sage Publications.

Mills, J., J. Schmitz, et al. (2004). "A strategic review of "supply networks"." International Journal of Operations and Production Management **Vol. 24**(No. 10): PP.1012-1036.

Mohanty, R. and S. Deshmukh (1993). "Use of Analytic Hierarchic Process for Evaluating Sources of Supply." International Journal of Physical Distribution & Logistics Management **Vol. 23** (No. 3): PP.22-28.

Morgan, J. and R. M. Monczka (1995). "Alliances for new products." Purchasing **Vol. 118** (No.1): PP.103-9.

Nagano, F., T. Yamaguchi, et al. (1995). "DEA with fuzzy output data" Journal of the Operations Research Society of Japan **Vol. 40**: PP. 425-429.

Naylor, J. B., M. M. Naim, et al. (1999). "Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain. ." International Journal of Production Economics **Vol. 62**: PP. 107-118. .

Neely, A., Ed. (2003). Business Performance Measurement: Theory and Practice, United Kingdom at the University Press, Cambrige.

Neely, A., M. Bourne, et al. (2000). "Performance measurement system design: developing and testing a process-based approach." International Journal of Operations and Production Management **Vol. 20**(No. 10): PP. 1119-1145.

Neely, A., M. Gregory, et al. (1995). "Performance measurement system design: A literature review and research agenda " International Journal of Operations & Production Management **Vol.15** (No. 4): PP. 80-116

Neely, A., M. Gregory, et al. (2005). "Performance measurement system design-Aliterature review and research agenda." international Journal of Operations and Production Mnagement **Vol. 25**(No. 12): PP. 1228-1263.

Neely, A., J. Mills, et al. (2000). "Performance measurement system design: developing and testing a process-based approach." International Journal of Operations and Production Management **Vol. 20**: PP. 1119-1145.

Neely, A. D., M. Gregory, et al. (1995). "Performance measurement system design." International Journal of Operations and Production Management **Vol. 15**: PP. 80-116.

Neuman, W. L. (2000). Social research methods: qualitative and quantitative approaches, 4 th Edition. Nedham Heights: Pearson Education Company.

News Analysis (2009). "China's Car Sales Jump 47% Year over Year on Subsidies; Extends Lead as Largest Global Market " Available on: http://www.forexhound.com.

Niang, B. and C. Bo (2007). "How Railway Container Transportation Merge into Modern Supply Chain." RAILWAY TRANSPORT AND ECONOMY **Vol. 9**: PP. 14-21.

Nightingale, P., T. Brady, et al. (2003). "Capacity utilization revisited: software, control and the growth of large technical systems." Industrial and Corporate Change, Oxford University Press **Vol. 12**(Number 3,): PP. 477-517.

Norman, M. and B. Stoker (1991). Data Envelopment Analysis: The Assessment of Performance, John Wiley and Sons, New York, NY.

Nu, Y. and J. Zhang (2006). "A Study on the E-business Application of Automobile Industry" Science and Technology Progress and Policy **Vol. 2**: PP. 91-93.

Ohno, T. (1988). Toyota Production System: Beyond Large-Scale Production (Hardcover), Productivity Press.

Oracle Consulting (2008). "ChangAn Auto Uses Experienced Consultants to Build Comprehensive

IT Infrastructure." Available on : http://www.oracle.com.

Organisation Internationale des Constructeurs d' Automobiles (OICA) Statistics (2009). "1998-2008 Global Vehicle Production Statistics." Available on: http://oica.net/category/production-statistics/.

Pao, Y. and W. W. Xiao (2007). "Study on Human Resources Quality and Human Resource Value." Computer Knowledge and Teconology **Vol 18**: PP. 301-306.

Paul. D, L. and J. E.Ormrod (2001). Practical Research: Planning and Design. (7th Ed), Upper Saddle River, NJ: Merrill Prentice Hall.

Ping, X. and W. King (2009). "China Retools its Auto Industry to meet Global Challenges" Available on: http://www.chinalawinsight.com.

Poh, K. L. and W. Ang (1999). "Transportation fuels and policy for Singapore: an AHP planning approach " Computers & Industrial Engineering **Vol. 37**(Issue 3): PP. 507-525

Poirier, C., C and S. Reiter, E, Eds. (1996). Supply chain optimization, Berrett-Koehler Publishers, San Francisco, CA

Qi, B. and j. Chen (2008). "China's auto sales exceed 8 millions in 2007." Available at China Association of Automobile Manufacturers : http://www.caam.org.cn/.

Qian, J. and B. Meng (2007). "China's Huachen Automotive plans growth models." Asia Pulse News **Vol. 3**: PP. 38-39.

Qiao, Y. and D. z. Feng (2009). "Analysis the Importance of Employee's Training Program Standardization to Manufacturers –Based on Toyota Company " POPULAR BUSINESS **Vol. 7**(Issue 11): PP. 42-56

Ramadhan, R. H., H. I. A.-A. Wahhab, et al. (1999). "The use of an analytical hierarchy process in pavement maintenance priority ranking" Journal of Quality in Maintenance Engineering **Vol. 5**(Number 1): PP. 25-39

Rangone, A. (1996). "An analytical hierarchy process framework for comparing the overall performance of manufacturing departments." International Journal of Operations and Production Management **Vol. 16**(No. 8): PP. 104-119.

Remenyi, D. (2004). Historiography as a research method in business and management studies Proceedings of the 3rd European Conference on Research Methodology for Business and Management Studies.

Riege, A. M. (2003). "Validity and reliability tests in case study research: a literature review with "hands-on" applications for each research phase." Qualitative Market Research: An International Journal **Vol. 6**(Issue: 2): PP. 75 - 86.

Robson, C. (2002). Real World Research (2nd Ed), Blackwell, Oxford.

Rolstandas, A. (1995). "Performance measurement :A business process benchmarking approach." Chapman and Hall, New York, NY.

Roth, A. V. (1996). Neo-operations strategy: linking capabilities-based competition to technology, Handbook of Technology Management. McGraw-Hill, NY,.

Rubesch, E. and R. Banomyong (2005). "Selecting suppliers in the automotive industry: Comparing international logistics costs." Asia Pacific Journal of Marketing and Logistics **Vol. 17**(No. 5): PP. 61-69.

Rubin, H. and I. Rubin (1995). Qualitative interviewing: The art of hearing data, Thousand Oaks, CA: Sage.

Rushton, A. (2001). Handbook of Logistics and Distribution Management [ILLUSTRATED] (Paperback) 2 edition, Kogan Page, London.

Sánchez, A. M. and M. P. Pérez (2005). "Supply chain flexibility and firm performance-A conceptual model and empirical study in the automotive industry " International Journal of Operations and Production Management **Volume 25**(Number 7): PP. 681-700

Saad, M. and B. Patel (2006). "An investigation of supply chain performance measurement in the Indian automotive sector." Benchmarking: An International Journal **Vol. 13**(No. 1/2,): pp. 36-53.

Saaty, T. L. (1983). "Priority setting in complex problems " IEEE Transaction on Engineering Management **Vol. EM-30,**: PP. 140-155, .

Saaty, T. L. (1994). Fundamentals of Decision Making and Priority Theory With the Analytic Hierarchy Process (Paperback) RWS Publications; First edition

Saaty, T. L. (2001). Decision Making with Dependence and Feedback: the Analytic Network Process, RWS Publisher, Pittsburgh, PA

Saaty, T. L. (2005). Theory and applications of the analytic network process: Decision making with benefits, opportunities, costs and risks, RWS Publications.

Saaty, T. L., Ed. (2005). Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks, RWS Publications, Pittsburg, PA, USA.

Saaty, T. L. and J. M. Alexander (1981). Thinking with Models: Mathematical Models in the Physical. Biological and Social Sciences., Pergamon Press, London.

Sahay, B. S., J. N. D. Gupta, et al. (2006). "Managing supply chains for competitiveness: the Indian scenario." Supply Chain Management: An International Journal **Vo.11**(No.1): PP.15-24.

Sahay, B. S. and R. Mohan (2006). "3PL practices: an Indian perspective." International Journal of Physical Distribution & Logistics Management **Vol. 36**(No. 9): PP. 666-689.

Sakakibara, S., B. Flynn, et al. (1997). "The impact of just-in-time manufacturing and its infrastructure on manufacturing performance." Management Science **Vol. 43** (No. 9): PP. 1246-1257.

Sarkar, A. and P. K. J. Mohapatra (2008). Maximum utilization of vehicle capacity: A case of MRO items, Pergamon Press, Inc. Tarrytown, NY, USA

Satty, T. L. (1995). Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World., RWS Publications,. Pittsburgh.

Saunders, M. (2003). Research methods for business students, Pearson Education Limited, Harlow, England.

Saunders, r., P. Lewis, et al., Eds. (2009). Research Methods for Business Students, Prentice Hall.

Schmitt, B. (2010). "Car Sales Around The World In 2009: Mostly Down." Available on: http://www.thetruthaboutcars.com.

Schniederjans, M. J. and R. L. Wilson (1991). "Using the analytic hierarchy process and goal programming for information system project selection " Information & Management **Vol. 20** (No.5): PP. 333-342

Schonberger, R. J. (1990). Building a Chain of Customers (Hardcover) Free Press, London

Schroeder, R., J. C. Anderson, et al. (1986). White collar productivity measurement, Management Decision, Vol 24 (5), PP. 3-7.

Seiford, L. (1996). "Data envelopment analysis: the evolution of the state of the art." The Journal of Productivity Analysis **Vol. 7**: PP. 99-137.

Shanghai Auto (2006). "The Execution of SAP IS-AUTO Solution in Shanghai General Motors." China Auto Market **Vol.11**: PP. 23-24.

Shao, C. (2009). "The Implication of Fuzzy Comprehensive Evaluation Method in Evaluating Internal Financial Control of Enterprise." International business research **Vol.1**(Issue 1): PP.

210-214.

Shark, C. (2008). "BMW opens regional distribution center in Foshan." People's Daily **July**.

Shen, Z. C. (2008). "China's demand to logistics professionals to exceed 300,000 by 2010" Available on : http://www.atimes.com/.

Sheng, D. A. and W. Zhong (2008). "Optimization of Routing Arrangement Schemes Based on Fuzzy Programming." Transactions of Beijing Institute of Technology **Vol. 8**: PP. 41-53.

Shepherd, C. and H. Gunter (2006). "Measuring supply chain performance: current research and future directions." International Journal of Productivity and Performance measurement **Vol. 55** (No. 3/4): PP. 242-258.

Shore, B. and A. R. Venkatachalam (2003). "Evaluating the information sharing capabilities of supply chain partners--A fuzzy logic model " International Journal of Physical Distribution and Logistics Management **Vol. 33** (Number 9): PP. 804-824

Sina Analysis (2010). "Analysis on 2009 Global Automotive Industry " Available on: http://auto.sina.com.cn/news.

Slack, N., S. Chambers, et al. (1995). Operations Management, Pitman Publishing, London.

Smith, M. E., R. Thorpe, et al. (1991). Management Research: An Introduction, Sage Publications, London.

Song, C. Y. (2007). "A Research on the Chain Management Model of Human Resource Management." Journal of Central University of Financel and Economics **Vol. 12**: PP. 240-251.

Song, Y. and F. Chen (2006). "Customer relationship management application in Shanghai- General motor." Enterprise Management **Vol. 11**: PP. 33-38.

Spekman, R. E., J. K. Jr, et al. (1998). "An empirical investigation into supply chain management-A perspective on partnerships." International Journal of Phhysical Distribution & Logistics **Vol. 28**(No. 8): PP. 630-650.

Srivastara, S. K. (2007). "Green Supply-Chain Management: A State-of-The-Art Literature Review." International Journal of Management Reviews **Vol. 9** PP. 53-80.

Stainer, A. (1997). "Logistics - a productivity and performance perspective " Supply Chain Management: An International Journal **Vol. 2** (No. 2): PP. 53-62.

Stake, R. (1995). The art of case research, Thousand Oaks, CA: Sage Publications.

Stewart, B. (2006). "Bennett Stewart explains EVA--the real key to creating wealth" http://www.sternstewart.com/evaabout/whatis.php.

Stewart, G. (1995). "Supply chain performance benchmarking study reveals keys to supply chain excellence." Logistics Information Management **Vol. 8**(No. 2): PP. 38-44.

Stiles, J. (2003). "A philosophical justification for a realist approach to strategic alliance research." Qualitative Market Research: An International Journal **Vol. 6**(Issue: 4): PP.263 - 271.

Stoop, P. P. M. and J. W. M. Bertrand (1997). "Performance prediction and diagnosis in two production departments." Integrated Manufacturing Systems **Vol. 8**(No. 2): PP. 103-109.

Sun, H. T. (2009). "Supply Chain Management for Competitive Advantage " NORTHERN ECONOMY AND TRADE **Vol. 10**: PP. 217-228.

Sun, X. H., G. Z. Ma, et al. (2004). "Analysis of the training method for the automobile enterprises " Wool Textile Journal **Vol. 08**: PP. 38-52.

Sutton, R. I. and A. L. Callahan (1986). Bankruptcy as stigma: An empirically-based theory, Academy of Management Meetings, Chicago.

Ta, H. P. and K. Y. Har (2000). "A study of bank selection decisions in Singapore using the Analytical Hierarchy Process " International Journal of Bank Marketing **Vol. 18** (No. 4): PP. 170-180

Tan, K. C., R. B. Handfield, et al. (1998). "Enhancing firm's performance through quality and supply base management: an empirical study." International Journal of Production Research **Vol. 36** (No.10): PP. 2813-37.

Tan, K. C., S. B. Lyman, et al. (2002). "Supply chain management: a strategic perspective." International Journal of Operations & Production Management **Vol. 22**: PP: 614-631.

Tan, K. H., K. Platts, et al. (2004). "Building performance through in-process measurement: Toward an "indicative" scorecard for business excellence." International Journal of Productivity and Performance Management **Vol. 53**(No. 3): PP: 233 - 244

Tang, D. and X. Qiana (2007). "Product lifecycle management for automotive development focusing on supplier integration " Computers in Industry **Volume 59**(Issues 2-3): Pages 288-295

Tech Republic (2006). "ChangAn Opens Communication Lines With Oracle." Available on Tech Republic:http://whitepapers.techrepublic.com.

Tews, J. (2008). "J.D. Power Asia Pacific Reports: Rising Expectations among New-Vehicle Buyers in China Lead to Decrease In Overall Sales Satisfaction." Available on:

http://www.free-press-release.

Tsang, A. H. C., A. K. S. Jardine, et al. (1999). "Measuring maintenance performance: a holistic approach " International Journal of Operations & Production Management **Vol. 19** (No. 7): PP. 691-715.

Tu, Q. and X. H. Xu (2006). "Research on Supply Chain Management Model of DongFeng Commercial Vehicle " Pioneering With Science and Technology Monthly **Vol 3** (Issue. 12): PP. 131-133.

Turner, K. and G. Williams (2005). "Modeling complexity in the automotive industry supply chain." Journal of Manufacturing Technology Management **Vol. 16** (4): PP. 447 - 458.

Tzeng, G.-H., M.-H. Teng, et al. (2002). "Multicriteria selection for a restaurant location in Taipei " International Journal of Hospitality Management **Vol. 21**(Issue 2): PP. 171-187

USA Today News (2010). "China surpasses U.S. in 2009 auto sales." Available on: http://www.usatoday.com/money/autos/2010-01-08-china-auto-sales_N.htm.

Vargas, L. G. (1990). "An overview of the analytic hierarchy process and its applications." European Journal of Operational Research **Vol. 48** (Nov. 1): PP. 2-8.

Vickery, S., C. Droge, et al. (1997). "Dimensions of competitive strength in manufacturing: an analysis of competitive priorities in the furniture industry." Journal of Operations Management **Vol. 15**: PP. 317-330.

Vickery, S. K., J. Jayaram, et al. (2003). "The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships" Journal of Operations Management **Vol. 21**(No. 5): PP. 523-539.

Vlasic, B. and N. Bunkley (2008). "Hazardous Conditions for the Auto Industry " Available on: http://www.nytimes.com/2008/10/02/business.

Vokurka, R. J. and S. W. O'Leary-Kelly (2000). "A review of empirical research on manufacturing flexibility." Journal of Operations Management **Vol. 18**: PP. 485-501.

Vorst, J. G. A. J. v. d., S. J. v. Dijk, et al. (2001). "Leagile supply chain design in food industry; an inflexible poultry supply chain with high demand uncertainty." International Journal on Logistics Management **Vol. 12**(No. 2): PP. 73-85.

Wabalickis, R. N. (1987). "Justification of FMS with the analytic hierarchy process." Journal of Manufacturing Systems, **Vol. 7** (No. 3): PP.175-82.

Waggoner, D. B., A. D. Neely, et al. (1999). "The forces that shape organizational performance measurment systems: an interdisciplinary review." International Journal of Production Economics **Vol. 60**: PP. 53-60.

Waller, B. (2003). "Fishing around for downstream profits." Available on: www.automotivelogisticsmagazine.com.

Wang, G. and L. Yuan (2006). "The Effect of the Infrastructure Investment Flows on the Economic Growth." Technology economics **Vol. 32**: PP. 298-311.

Wang, J. and J. Xie (1996). System Engineering Foundation and Application, Beijing: Geological Publishing House.

Wang, K. (2008). "General situation of industry development." Available on: www.autologistics.org.

Wang, l. and X. Ma (2008). "Analysis on Econometric Model of Demand of Chinese Civil Automobile " Journal of Shanxi Economic management institute **Vol. 1**: PP. 21-23.

Wang, M. (2008). "Externality Analysis of Third Party Logistics and Government Countermeasures " Journal of Huangshang University **Vol. 3**: PP. 34-44.

Wang, P. and L. Han (1989). Fuzzy Systems and Mathematics, Beijing Institute of Economy.

Wang, Q. y. and G. q. Zhang (2007). " Economic Globalization and Economic Logistics " Journal of Transportation Systems Engineering and Information Technology **Vol. 6**: PP.12-15.

Wang, T. l. and Y. Q. Chi (2004). "Elementary Research of Principle and Method on Performance Evaluation of Modern Logistics Companies." Logistics Management **Vol. 27**(No. 10).

Wang, X. and S. Yu (2006). "Create a financial service system for automobile consumption and improve its quality." Consumer Economics **Vol. 12**.

Warner, F. and D. Bank (1999). "Ford, MS to offer build-it-yourself cars." The Wall Street Journal Online **available at: http://news.zdnet.com/2100-9595_22-515723.html**.

Webster, M. (2002). "Supply system structure, management and performance: a conceptual model." International Journal of Management Reviews **Vol. 4** (No. 4): PP.353-369.

Wei, J. X., P. Yan, et al. (2009). "Demand Analysis on the Enterprise Resources Plan in Automobile Industry " Tian Jin Auto **Vol. 6**( ): PP. 156-178.

Wei, X. (2007). "Reference and Revelation of Status of German Logistics to Chinese Logistics Development " Railway Freight Transport **Vol. 3**: PP. 18-23.

Welman, J. C. and S. J. Kruger (1999). Research methodology for the business and administrative sciences, Johannesburg, South Africa: International Thompson.

Weng, D. Z. and F. Yu (2009). "How to conduct training programme in the manufacturing industry in the future --training at Toyota corporation." POPULAR BUSINESS **Vol. 7**: PP. 112-124.

Weng, Z. K. (1999). "Strategies for integrating lead time and customer-order decisions." IIE Transactions **Vol. 31**: PP. 161-171.

Wenzhou University (2008). "University news-Education and Careers: Professional Development " Available on: http://www.wzu.edu.cn/NewsShow.

Wikipedia Website (2010). "Artificial neural network." Available on: http://en.wikipedia.org/wiki/Artificial_neural_network.

Womack, J. P. and D. T. Jones (1996). LEAN THINKING : Banish Waste and Create Wealth in Your Corporation (Hardcover).

Wong, W. P. and K. Y. Wong (2007). "Supply chain performance measurement system using DEA modeling." Industrial Management And Data Systems **Vol. 107**(No. 3): PP. 361-381.

Wu, F. and W. Zhao (2004). "Training of Enterprise Employees After Practicing ERP " Journal of Beijing University of Technology (Social Sciences Edition) **Vol. 3**: PP. 56-62.

Wu, M. S. and J. Chen (2009). "The study of Human Resource Planning (HRP) Based on Human Resource Cost (HRC) " China Management Inofrmationization **Vol. 5**: PP. 21-24.

Wu, P. (2005). "Logistics management in automotive corporations of China." Research paper.

Wu, Q. (2006). "Development of logistics undertaking and pallet standardization in China." China Federation of Logistics & Purchasing: PP. 61-69.

Wu, S. and J. Chu (2009). "Study on the Cause of the Automobile Productivity Surplus and its Solution " Science technology and industry **Vol. 2**: PP. 133-143.

Wu, Y. and J. He (2006). "The Analysis of the Third-party Logistics in China " Loistics Management **Vol. 3**: PP. 53-55.

Xian, L. and G. S. Wu (2008). "Evolution of Strong Powers in World Automobile Industry and Its Implications to China " China Soft Science **Vol. 67**: PP. 72-79.

Xiao, C. q. and X. Rong (2008). "Auto industry profit rises 62.89% despite price cuts." Available on: http://www.chinadaily.com.cn/business.

Xie, K. (2007). "How to Optimize and Operate SCM of Manufacturing Enterprise Group." Logistics technology **Vol. 10**: PP. 95-97.

Xinhua News (2007). The national report on automotive industry. Invest in Zhejiang province.

Xu, G. and C. Y. Tian (2009). "Design and Implementation of Automobile Information System Based on Web." Application Research of Computers **Vol. 15**: PP. 82-86.

Xu, W., X. Jing, et al. (2007). "China becoming BMW's largest market." Available on: http://autonews.gasgoo.com/china-news.

Yan, A. (2009). "Dongfeng Peugeot to add 4 new models by 2010." Available on: www.gasgoo.com/auto-news.

Yan, G. and G. Bin (2009). The Government's Role in Today's Auto Crisis. Fourth International Conference on Cooperation and Promotion of Information Resources in Science and Technology.

Yan, T. (2008). "Time for SAIC to improve range of vehicle." Available on: english.chinabuses.com

Yang, H. and F. Chen (2008). "Product Lifecycle Management for the automotive industry." Available on: www.automotive-business-review.com.

Yang, J. and H. Lee (1997). "An AHP decision model for facility location selection." Facilities **Vol. 15**(No. 9/10): PP. 241-254.

Yang, X. h. and M. Pillsbury (2007). Globalization of the automobile industry : the United States, Japan, and the People's Republic of China, Greenwood Publishing Group.

Yin, J. J. and X. M. Zhang (2005). "Innovated Methodology of Performance Evaluation of China's Listed Companies " Modern Economic Science **Vol. 6**: PP. 161-173.

Yin, R. K. (1999). "Enhancing the Quality of Case Studies in Health Services Research." Health Services Research **Vol. 34**(Issue 5 (Part 2)): PP. 1209-1224.

Ying, T. (2009). "China February Auto Sales Rise 25% After Tax Cuts" Available on: http://www.bloomberg.com/apps/news.

Yinghong, G. and L. Bin (2008). The Development of Automotive Spare Parts Industry: Future Challenge and Opportunity The 15th International Conference on Industrial Engineering and Engineering Management.

You, J. X. and Y. M. Zhu (2005). "The Application and Improvement of Supply Chain Network Model in the Automobile Industry " Industrial Engineering and Management **Vol. 6**: PP. 407-417.

Yuan, Q. (2008). "An analysis of talented person demand in China " China Water Transport (Academic Version) **Vol. 5**: PP. 72-76.

Yuan, X. and G. Jiang (2007). "Report on the Development of China's Logistics." Logistics Association China New Release.

Yurdakul, M. (2002). "Measuring a manufacturing system's performance using Saaty's system with feedback approach " Integrated Manufacturing Systems **Vol. 13** (No. 1): PP. 25-34

Zadeh, L. A. (1978). "Fuzzy sets as a basis for a theory of possibility." Fuzzy Sets and Systems **Vol. 1**: PP. 3-28.

Zhang, J. (2007). "Highway Development in China." Ministry of Communications, China Association of Automobile Manufacturers: PP. 171-189.

Zhang, L. (2006). " Conforming China automobile logistics supply with forth party logistics " Special Zone Economy **Vol. 5**: PP. 27-35.

Zhang, Q. Y., M. A. Vonderembse, et al. (2002). "Value Chain Flexibility: a Dichotomy of Competence and Capability." International Journal of Production Research, **Vol. 40**(No. 3): PP. 561-583.

Zhang, W. (2006). "The Supervision Theory of Employee's Satisfaction and its Application" Journal of Shangdong Institute of Business and Technology **Vol. 5**: PP. 20-23.

Zhang, W. Q. (2005). "The Supervision Theory of Employee's Satisfaction and its Application" Journal of Shangdong Institute of Business and Technology **Vol. 5**: PP. 77-91.

Zhang, X. and R. Chen (2006). "Forecast-driven or customer-order-driven? An empirical analysis of the Chinese automotive industry." International Journal of Operations & Production Management **Vol. 26**(No. 6,): pp. 668-688.

Zhang, Y., Y. Lin, et al. (2002). "Multi-objects Fuzzy Comprehensive Evaluation of Sea-going Cargo Ship by AHP." System Engineering Theory and Practice **Vol.11**: PP.129-133.

Zhao, J. and J. Xiong (2008). "Spare Parts Inventory Management Based On Supply Cost." Techniques of automation and applications **Vol. 9**: PP. 28-32.

Zhao, J. Y. (2008). "The practice Of Logistics standardization management of JAC Motors." LOGISTICS AND MATERIAL HANDLING **Vol. 12**(Issue: 13): PP. 101-P104.

Zhao, Q. and J. Li (2008). "Model and Algorithms of Supply and Demand Coordination Performance Measurement Based on ANP Theory." Computer Integrated Manufacturing Systems

Vol. 23: PP.123-125.

Zheng, A. (2009). "Discussion on the Selection of the Developing Mode of Chinese Automobile Industry " Science and Information Development **Vol. 5**: PP. 50-58.

Zheng, J. and R. Su (2008). "Present Situations of Chinese Supply chain Industry and Countermeasures " Journal of South-West University for Nationalities (Philosophy and Social Sciences) **Vol. 1**: PP. 98-110.

ZhengJiang Auto News (2010). "Report on China Automotive Industry in 2009." Available on: http://auto.zjol.com.cn

Zhong, M. and X. Xie (2008). "Cost Analysis of Supply Chain Facility in the Chinese Automotive Supply Chain." Journal of Dalian Maritime University **Vol. 4**(Issue 4): PP. 14-18.

Zhou, A. L., X. H. Li, et al. (2009). "Present Situations and Corresponding Proposals of Logistics Standardization in China." JOURNAL OF HIGHWAY AND TRANSPORTATION RESEARCH AND DEVELOPMENT **Vol 20 (2)**: PP. 242-259.

Zhou, L., S. Deng, et al. (2006). "To be pragmatic with high efficiency-The thinking of HaFei " China Auto Market **Vol. 1**: PP. 69-73.

Zhou, W., N. Xue, et al. (2007). "The Investigation on the Reasons of Vehicle Shortage " LOGISTICS TECHNOLOGY **Vol. 26 (10)** PP. 224-253.

Zhu, J., F. Jiang, et al. (2007). "Study on Customer Information Sharing in the Supply Chain of Automobile " Information Science **Vol. 7**: PP. 311-323.

Zhu, Q. and Y. Geng (2001). "Integrating environmental issues into supplier selection and management: a study of large and medium-sized state-owned enterprises in China." Greener Management International **Vol. 35**: PP. 27-40.

Zhu, Q., J. Sarkis, et al. (2006). "Green supply chain management: process, practices and performance within the Chinese automotive industry." Journal of Cleaner Production **Vol. 1-12**.

Zhu, S. and J. Wang (2008). "The Review and Forecast of China's Auto Market " Shanghai Auto **Vol. 4**: PP. 6-11.

Zhu, X. (2005). Research into the Subjective Evaluation Method (5th Edition), Southeast University Press, Nan Jing.

Zimmermann, K. and S. Seuring (2009). "Two case studies on developing, implementing and evaluating a balanced scorecard in distribution channel dyads." International Journal of Logistics: Research and Applications **Vol. 12**(No. 1): PP. 63-81.