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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"MEASUREMENT OF SUPPLY CHAIN PERFORMANCE IN SELECT AUTOMOTIVE INDUSTRIES IN INDIA"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Management Studies of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from July, 2010 to February, 2015 under the supervision of Dr. Mukesh Kumar Barua, Associate Professor, Department of Management Studies, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

(RAJESH KATIYAR)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: (Mukesh Kumar Barua)
(Supervisor)

Abstract

Today, India is emerging as one of the world's fastest passenger car marketplaces and the second largest manufacturer of two wheelers. The primary reason behind concentrating on automotive industry here is that it is the fastest growing sector in India and has more than 10% contribution to the Indian GDP. Many international automotive companies such as Honda, Ford, and Toyota etc. have entered in the Indian passenger car market after changes in foreign investment policies of India. It has fuelled competition among automotive companies, in terms of product cost, delivery, quality, and flexibility. To compete in market, companies are aiming to improve the overall performance of their supply chains. Such causes emphasize the need of developing a model to measure supply chain performance in the Indian automotive sector. One of the major challenges before the Indian automotive firms is to ascertain the factors that affect supply chain performance and interrelationship among these factors. Identification of barriers in supply chain performance measurement is another perplexing issue for many automotive firms. Further, suppliers play a vital role in achieving an efficient and effective supply chain for any organization. Therefore, it is equally important to explore and rank the factors that affect supplier's performance. The motivation of the current research emanates from these issues.

In this thesis, various constructs and their key factors are identified based on literature review and experts' opinion that affect supply chain performance measurement. Moreover, a conceptual framework has been developed that includes five constructs with their twenty key factors to measure supply chain performance in the Indian automotive sector. A questionnaire was prepared based on the identified constructs and their factors and then various brainstorming sessions and interviews were conducted with managers from the Indian automotive sector.

Both qualitative and quantitative methods are used to analyse and measure supply chain performance. Interpretive structural modeling (ISM) technique was used to examine the interrelationships among key factors as well as barriers of supply chain performance measurement in the Indian automotive sector. Further, a fuzzy analytic hierarchy process (fuzzy AHP) based hierarchical model is developed for supplier selection and prioritizing the factors that affect suppliers' performance in the Indian automotive sector. Finally, a scale and conceptual model are developed to measure supply chain performance and to delve the relationships of different constructs and their key factors with overall supply chain performance. Various hypotheses were proposed to investigate the relationships of various constructs with overall supply chain performance. Partial least square (PLS) and structural equation modelling (SEM) techniques are used to test the proposed hypotheses.

Keywords: Supply chain, Performance measurement, Supply chain performance measurement, Key factors, Barriers, Supplier selection, Interpretive structural modeling, Fuzzy analytic hierarchy process, Partial least square, Structural equation modeling, Automotive sector, India.

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This work is dedicated to:

"Those I met on this journey who feels compelled to live their lives as examples, with reflective and passionate consideration for other, themselves, and the world around them"

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(RAJESH KATIYAR)

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List of Abbreviations

Abbreviations	Full Name
ACMA	Automobile Component Manufacturing Association
AHP	Analytic Hierarchy Process
AMOS	Analysis of Moment Structures
ANOVA	Analysis of Variance
ANP	Analytic Network Process
AVE	Average Variance Extracted
BSR	Buyer Supplier Relationship
CFA	Confirmatory Factor Analysis
COP	Customer Order Path
CQT	Customer Query Time
CR	Composite Reliability
CS	Customer Service
CSP	Customer Service Performance
CU	Capacity Utilization
D	Delivery
DEA	Data Envelopment Analysis
DEMATEL	Decision Making Trial and Evaluation Laboratory
DLT	Delivery Lead Time
DP	Delivery Performance
DRM	Direct Relationship Matrix
EDIM	Effectiveness of Delivery Invoice Methods
EFA	Exploratory Factor Analysis
EMPS	Effectiveness of a Master Production Schedule
F	Flexibility
FAD	Fuzzy Axiomatic Design
FDRM	Fuzzy Direct Relationship Matrix
FDSMPCN	Flexibility of Delivery Systems to Meet Particular Customer Needs
FMPCN	Flexibility to Meet Particular Customer Needs

FRM	Final Reachability Matrix
FSSMCN	Flexibility of Service System to Meet Customer Needs
Fuzzy AHP	Fuzzy Analytic Hierarchy Process
Fuzzy MICMAC	Fuzzy Cross Impact Matrix Multiplication Applied to Classification
Fuzzy TOPSIS	Fuzzy Technique for Order Preference by Similarity to Ideal Solution
GDP	Gross Domestic Product
GoF	Goodness of Fit
GSC	Green Supply Chain
GSCM	Green Supply Chain Management
HCV	Heavy Commercial Vehicles
HM	Hindustan Motors
ICC	Information Carrying Cost
IRM	Initial Reachability Matrix
IT	Information Technology
JIT	Just in Time
LCV	Light Commercial Vehicles
LISREL	Linear Structural Relations
M	Manufacturing
MADM	Multiple Attribute Decision Making
MASP	Mutual Assistance in Solving Problems
MC	Manufacturing Cost
MCDM	Multi Criteria Decision Making
MICMAC	Cross Impact Matrix Multiplication Applied to Classification
MP	Manufacturing Performance
NN	Neural Network
OEM	Order Entry Method
OLT	Order Lead Time
OTDG	On Time Delivery of Goods
P	Plan
PAL	Premier Automobiles Limited
PC	Product Cost
PLS	Partial Least Square

PM	Performance Measurement
PMS	Performance Measurement System
POCT	Purchase Order Cycle Time
PP	Plan Performance
PTMCS	Post Transaction Measures of Customer Service
Q	Quality
QFD	Quality Function Deployment
RPS	Range of Product and Services
RQ	Research Question
R&D	Research and Development
S	Source
SAP-LAP	Situation Actor Process Learning Action Performance
SC	Supply Chain
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SCP	Supply Chain Performance
SCPM	Supply Chain Performance Measurement
SEM	Structural Equation Modeling
SIAM	Society of Indian Automobile Manufacturers
SME	Small and Medium Sized Enterprises
SP	Source Performance
SS	Supplier Selection
SSIM	Structural Self Interaction Matrix
TIC	Total Inventory Cost
TFN	Triangular Fuzzy Number
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TQM	Total Quality Management
UK	United Kingdom
USA	United States of America
W	Weight

CHAPTER 1
Introduction

Preview

This chapter presents a brief background of the present study. It begins with the details of the problem statement, motivation for the present research, research objectives and research questions, and overview of the present study. At last, a brief summary of the subsequent chapters of this thesis is given.

1.1 Background of the present study

The Indian automotive industry came into being in the 1950s, and has grown-up since under a highly regulated and sheltered economic background (Saad and Patel, 2006). The automotive supply chain (SC) is defined as a SC where a raw material of finished goods passes through different phases of production/manufacturing and distribution/delivery before reaching the final customer (Bijman, 2002; Aramyan, 2007). The Indian automotive firms' SC is different and complex from the western automotive SC. It consists of various categories like two wheelers, three wheelers, passenger cars, light commercial vehicles (LCVs), and heavy commercial vehicles (HCVs) etc. Changed foreign investment policies of the Indian government have emanated many international auto assemblers to enter in the Indian passenger car market. Nowadays, India is one of the world's best passenger car marketplaces and the second largest producer of two wheelers. It has been fastest growing sectors in India and has more than 10% contribution in Indian gross domestic product GDP (Joshi *et al.*, 2013). Fierce competition has compelled the firms to reduce costs, lead-time, improve quality, supply chain performance (SCP) etc. To achieve these targets, active as well as new organizations are attempting to improve their SCs and implement lean production methods. Saad and Patel (2006) observed that the Indian organizations have been attempting to introduce different approaches such as just-in-time (JIT) (Vrijhoef and Koskela, 2000), total quality management (TQM) (Wong and Fung, 1999), supply chain management (SCM) and other innovative concepts to improve the overall performance of organizations.

SCM is a concept that driven in the manufacturing sectors in the early-1980s (Chopra and Meindl, 2001). In manufacturing system, there is a need to develop for an enterprise to survie in the increasingly competitive global market (Mahdavi *et al.*, 2007). In past two decades, SCM literature has developed rapidly as a result of worldwide competition and the introduction of information technology (IT). Recently, manufacturing/buying organizations have invested in their suppliers to improve performance by developing long-lasting buyer-supplier relationships (Austin, 1990; Meena and Sarmah, 2012). However, there is a dearth of studies on SCP from the Indian perspectives. Since inception of the manufacturing period, performance measurement (PM) has been one of the challenging tasks for industries to understand what is happening around them (Chibba, 2007). SCP measurements literature can be divided into two different phases (Dixon *et al.*, 1990). The first phase includes literature till 1980s that focuses on financial measures; whereas, the second phase includes post 1980s literature that deals with new and emerging concepts in SCM. In current business environment, non-financial measures are equally crucial for improving and measuring SCP.

In literature, various performance indicators have been proposed to measure the performance of production processes, services, and products (Beamon, 1999; Ren *et al*., 2004; Koh and Demirbag, 2007). In order to improve SCP; there is a need to look outside the borders of individual firms. SCP is an overall PM that includes performance of different parties involve in SC of any firms (Gunasekaran *et al.*, 2004). According to Ren *et al.* (2004), planning and operations have significant impact on SCP. A number of studies highlight different performance measure needs to consider for measuring SCP (Van Hoek, 1998; Beamon, 1999; Lambert and Pohlen, 2001; Gunasekaran *et al.*, 2004; Shepherd and Gunter, 2006; Vereecke and Muylle, 2006; Saad and Patel, 2006; Koh and Demirbag, 2007). These studies have endeavored to outline and describe different key performance measures across and between organizations. Lambert and Pohlen (2001) observed that most of articles and discussions about SC measures are about internal logistic performance measures. It is now common knowledge that SCP key factors/measures play an important role in the journey towards business development. Focal industries across the world are trying to improve the performance of their SCs. Though, various studies are conducted on SCPM. However, very few attempts have been made on SCPM from the Indian perspectives. In this study, we have made an attempt to identify various constructs and their key factors for SCPM from the Indian automotive industry perspectives.

1.2 Supply chain performance measurement: An overview

SCPM is receiving incessant attention from practitioners and academicians (Bai and Sarkis, 2011). SCP is an overall performance measure that depends on the performance of different parties in SC. "The SCP can be defined by SC profitability, which has only one source of revenue-the customer" (Chopra and Meindl, 2001). PM is defined as the process of measuring the efficiency and effectiveness of action (Neely *et al.*, 1995). They recognized some PM approaches; criteria for measurement system design (Globerson, 1985); PM matrix (Keegan *et al.*, 1989), PM questionnaires (Dixon *et al.*, 1990), and balanced scorecard (Kaplan and Norton, 1992). Moreover, organizations are implementing various practices such as flexibility, operational performance, delivery performance, customer satisfaction, buyer-supplier relationship etc. to measure their performance (Ren *et al.*, 2004).

In today's business scenario, a long-term buyer-supplier relationship in SC is very essential for all business activities. Therefore, companies are adopting new ideas, strategies, technology, and techniques for improving their relationship with their suppliers (Sharma and Dixit, 1998; Hampel-Milagrosa, 2014). The adoption of any new strategy and idea also raised the needs to measure their effectiveness and efficiency. Moreover, order lead time, buyer-supplier relationship, quality, on time delivery of goods, flexibility to meet particular customer needs are some of the key factors used in practice to measure SCP (Gunasekaran *et al.*, 2001). It is necessary to develop a measurement framework that is relevant, comprehensive, and feasible to measure improvements in SCP. PM helps firms to make tradeoffs between investment and profit for improving performance (Neely *et al.*, 1994). This study specifically focuses on exploring the key factors that affect SCP of the Indian automotive industry.

1.3 Problem statement

In last few years, there has been a surge of publications in the area of SCP and PM from the academicians and practitioners. In current business scenario, SCM plays an essential role in any business activities for increasing firm's performance.) SCM is an important tool to enhance firm's efficiency and goals attainment (Gunasekaran *et al.*, 2001). PM is also an essential tool for industries to improve effectiveness, efficiency, and performance of their SC (Beamon, 1999; Neely *et al.*, 2002; Shepherd and Gunter, 2006; Bhattacharya *et al.*, 2014).

According to a famous management thinker Drucker (1992), "*what we can measure, we can manage*". Nowadays, one of the major challenges before organizations is to develop appropriate constructs for SCPM. Most of the Indian automotive firms are not implementing different ideas of SCPM effectively and only few Indian firms have effective strategies to measure SCP. Therefore, it is imperative to develop a system to measure SCP as it affects the overall performance of a system (Gunasekaran and Kobu, 2007; Ganga and Carpinetti, 2011). On the other hand, profit generation is also necessary for survival of any industry. According to Neely et al. (1994), effectiveness assessment of any strategy and its impact on firm's overall performance is an important issue.

In past two decades, various researchers around the world have developed some models for SCPM. SC logistics performance was probably one of the first attempts to define SCP (Chow *et al.*, 1994; Gunasekaran and Kobu, 2007; Chia *et al.*, 2009). Kaplan and Norton (1992) developed a balanced scorecard to assess business performance. Many researchers have studied various issues related SCPM such as major performance metrics (Beamon, 1999), categories of performance measures (Neely *et al.*, 1995), framework for measuring the strategic, tactical, and operational level (Gunasekaran *et al.*, 2001). However, there is a great dearth of literature that examine interrelationship among key factors of SCPM and with overall SCP from the Indian automotive industry perspectives. In order to fill this gap in literature the thesis focuses on the following important research issues:

- To investigate the interrelationships among the key factors of SCPM.
- To explore the interrelationships among the barriers of the Indian automotive SC.
- To select the best supplier of an automotive buying firm on the basis of suppliers' performance and their priority weight.
- To determine the overall supply chain performance, by developing a model for its assessment in context of the Indian automotive sector.

This research proposal will be a great help for the managers, practioners, decision makers, and scholars in the field of SCPM. First, it contributes to the body of literature. Second, it covers the existing gaps in the literature. Third, it will be very helpful for the practitioners and researchers who want to improve the SCP of the firm. Last, it will be helpful to the organization to set the benchmark for the industry.

1.4 Motivation and research issues

SCPM has been receiving incessant attention from the practitioners as well as from researchers since last two decades. Saad and Patel (2006) analyzed the structure of SCP measure and the difficulty of implementing such measures in the Indian automotive industry. It was found that the Indian automotive industries are not implementing the important concepts of SCM properly. Thus, decline in the business performance, inadequate product demand and poor quality towards customers is a problem of the current era that needs an immediate solution. These problems are motivating to undertake supply chain performance issues with the objective of increasing business performance of SC activities. Therefore, the performance of SC affects the overall performance of a system and a unique attribute of SCPM is that it measures the interdependencies that cross the borders of firms (Beamon, 1999; Gunasekaran *et al.*, 2001; Gunasekaran and Kobu, 2007). In this context, performance measurement is an essential tool for industries to improve efficiency and effectiveness of SC (Beamon, 1999; Shepherd and Gunter, 2006).

- In recent years, the number of publications in the field of supply chain performance has grown rapidly. There are several refereed International journals those are publishing research papers on various themes related to the supply chain performance. This amazing growth in the publication is providing better strategies, suggestions, and motivation for work in this field. Some of the journals are: International Journal of Production Economics, Supply Chain Management: An International Journal, Benchmarking: An International Journal, Computers & Industrial Engineering, International Journal of Logistics Systems and Management, Journal of Cleaner Production, International Journal of Production Research, Expert Systems with Applications, International Journal of Operations & Production Management, Production Planning and Control etc.
- For the present study, a literature review of SCPM was carried out using the keywords i.e. supply chain, performance measurement, supply chain performance, supply chain performance measurement etc. in online databases like Emerald Journal, Elsevier, EBSCO, Sage Journal, Taylor & Francis, Springer, and Google Scholar etc. The outcomes of this online search resulted in various studies on this issue across the globe. These studies reveal certain gaps need to explore in the future research.
- Supply chain performance measurement is a very demanding and important concept for the Indian automotive organizations. Very few studies are available in the literature in context of the Indian automotive firms (e.g. Husain *et al.*, 2002; Ravi and Shankar, 2005; Saad and Patel,

2006; Charan *et al.*, 2009; Kumar and Subrahmanya, 2010; Garg and Deshmukh, 2010; Joshi *et al.*, 2013; Vinodh *et al.*, 2013). Therefore, additional studies on this issue are the demand of the hour, so that Indian automotive industries can understand the advantages and disadvantages of improving firm's overall SCP.

- In literature, there was such no study included the SCPM key factors and developed an ISM-based model while examining the interrelationships among those factors by using ISM and fuzzy MICMAC technique in the Indian automotive industry. Similarly, there was dearth in literature about the barriers of supply chain performance measurement in the Indian automotive industry by using similar ISM and fuzzy MICMAC approach. These key factors of supply chain performance measurement and barriers help for the policy makers and managers to measure the SCP in the Indian automotive industry.
- During the literature review, a gap was identified which is related to the weight of the different constructs/attributes and their key factors/sub-attributes of SCPM and selection of best supplier for an Indian automotive buying firm. In other words, none of the studies provided the priority weights of above given attributes and sub-attributes and selection of best supplier on the basis of suppliers' evaluation and their performance by applying fuzzy AHP multi-criteria decision making (MCDM) technique. To fill this gap, fuzzy AHP, a well established and widely used MCDM technique has been used to prioritize the various constructs and their key factors of SCPM.
- The one most important gap which has been recognized after in-depth literature is that none of the studies have developed any measurement scale to measure the supply chain performance in the Indian automotive sector. For the scale development, well defined scale development method by Churchil (1979) was used to fulfil this gap. The scale development process has already been adopted in prior literature (e.g. Anderson and Gerbing, 1988; Bagozzi *et al.*, 1991; Nunnally and Bernstein, 1994; Hinkin, 1998; Magnus, 2006).
- The literature shows unavailability of any reliable and validated model to measure the overall supply chain performance in the Indian automotive industry. The research demand related to the SCPM in the Indian automotive sector is increasing, as this sector is growing rapidly in India. Therefore, an important need to have a model to fulfil this gap in an effective manner.
- Profit earning is one of the prime responsibilities of business organizations. In the Indian automotive sector, there is paucity in study that has measured the impact of supply chain

performance measurement constructs and their key factors on overall supply chain performance.

1.5 Research objectives and research questions

How to measure and then improve entire supply chain performance of a firm is a big issue in the current business scenario. The assessment of SCP measures and its impact on firm's overall SCP has been identified as an important issue that needs to be studied. From the various gaps that have been figured out from the literature on supply chain performance measurement, the topic of the present study is finalized as *"Measurement of supply chain performance in select automotive industries in India"*. This research is based on four main objectives as follows:

Objective 1: To identify and examine the interrelationship among the key factors of supply chain performance measurement in the Indian automotive industry.

Objective 2: To identify and examine the interrelationship among the barriers of supply chain performance measurement in the Indian automotive industry.

Objective 3: To select the best supplier providing the most buyer satisfaction of the Indian automotive industry.

Objective 4: To develop a model for measuring supply chain performance in the Indian automotive industry.

To achieve these objectives, five research questions have been formulated. These research questions provide the proper direction to attain the objectives of the study. These research questions are:

RQ 1: What are the various key factors/measures and barriers of supply chain performance measurement in the Indian automotive industry? (Chapter 2)

RQ 2: What is the relationship among the key factors of supply chain performance measurement in context of the Indian automotive industry? (Chapter 3)

RQ 3: What is the relationship among the barriers of supply chain performance measurement in context of the Indian automotive supply chain? (Chapter 4)

RQ 4: What are the weights and priority level of attributes/constructs and sub-attributes/key factors of supply chain performance measurement and the best supplier for the Indian automotive buying firm? (Chapter 5)

RQ 5: How these identified SCPM constructs influence the firm's overall supply chain performance? (Chapter 7)

H_1: Plan performance has positive impact on firm's overall SCP.

H_2: Source performance has positive impact on firm's overall SCP.

H_3: Manufacturing performance has positive impact on firm's overall SCP.

H_4: Delivery performance has positive impact on firm's overall SCP.

H_5: Customer service performance has positive impact on firm's overall SCP.

The first objective of this study is achieved through the research question 1 and 2. Second objective is attained through research question 1 and 3. Remaining 2 research questions (RQ 4 and RQ 5) help in attaining the third and fourth objective respectively.

1.6 Organization of the thesis

A chapter-wise summary of thesis is presented below and also depicted in Figure 1.1 that emphasized the specific problem and solution method suggested in this thesis.

Chapter 1

This chapter provides an introduction of the thesis and gave a brief introduction on supply chain performance and supply chain performance measurement. This chapter also discussed the research objectives of the study, motivation for the present study, a brief outline of research methodology used in this study, and a chapter-wise summary.

Chapter 2

The second chapter of this thesis provides a comprehensive review of literature in the field of supply chain performance with each of the problem studied in this thesis. This chapter covers general overview of supply chain performance and its assessment. In addition, it also provides the overview of Indian automotive sector. This chapter also provides a bibliographic classification of existing research in this field of study.

Chapter 3

This chapter presents the key factors of the supply chain performance measurement those were identified from the literature review and experts' opinion. Further, this chapter explores the interrelationships among identified key factors of the SCPM with the help of ISM and fuzzy MICMAC approach. An ISM technique was used to examine the interrelationships among the key factors of SCPM. Such relationships among the key factors will assist in the development of the entire process for the measurement and improvement of a firm's supply chain performance.

Chapter 4

This chapter deals with the problem of supply chain barriers in the Indian automotive industries. Barriers were also identified from the literature review chapter. Further, an ISM with a fuzzy MICMAC based approach was used to examine the interactions among the barriers in the Indian automotive supply chain. These barriers and their relationships help firm's top management in taking better decisions in order to improve the supply chain performance and provide a better approach to proactively deal with problems.

Chapter 5

This chapter investigates the problem of the best supplier selection and priorities of the supply chain performance measurement attributes, sub-attributes, and alternatives in the Indian automotive industry. Fuzzy AHP method was used to evaluate the ranking of the attributes and sub-attributes of the SCPM as well as for best supplier providing the most buyer satisfaction of Indian automotive industry. The weight of these SCPM attributes, sub-attributes and suppliers' ranking provide a better approach to improve the SCP.

Chapter 6

This chapter presents the conceptual framework proposed for the measurement of supply chain performance in context of the Indian automotive industries. In the subsequent part of this chapter, research objectives, questions, hypothesis, research methodology adopted in the present study are discussed. In addition, this chapter includes research design, scaling techniques, questionnaire design, sample design, data collection method and analysis process.

Chapter 7

This chapter investigates the problem of supply chain performance measurement in the Indian automotive industry. In addition, this chapter presents the application part of statistical techniques mentioned in the previous Chapter 6 to analyze the data. At the beginning, based on the literature review and opinion of the buyers, we explored different constructs abd their key factors that influence supply chain performance and subsequently a questionnaire was designed based on these factors. Five constructs and their twenty key factors were derived. Based on these constructs, different hypotheses are stated and a conceptual model is proposed to measure the firm's overall supply chain performance. A survey was conducted in the Indian automotive sectors. Partial least square (PLS) approach is used to validate the model and investigate the relationships of constructs with firm's overall supply chain performance.

Chapter 8

This chapter provides the summary, conclusions and contribution of the thesis. In addition, this chapter also provides the managerial implications of the present study and the scope for future work.

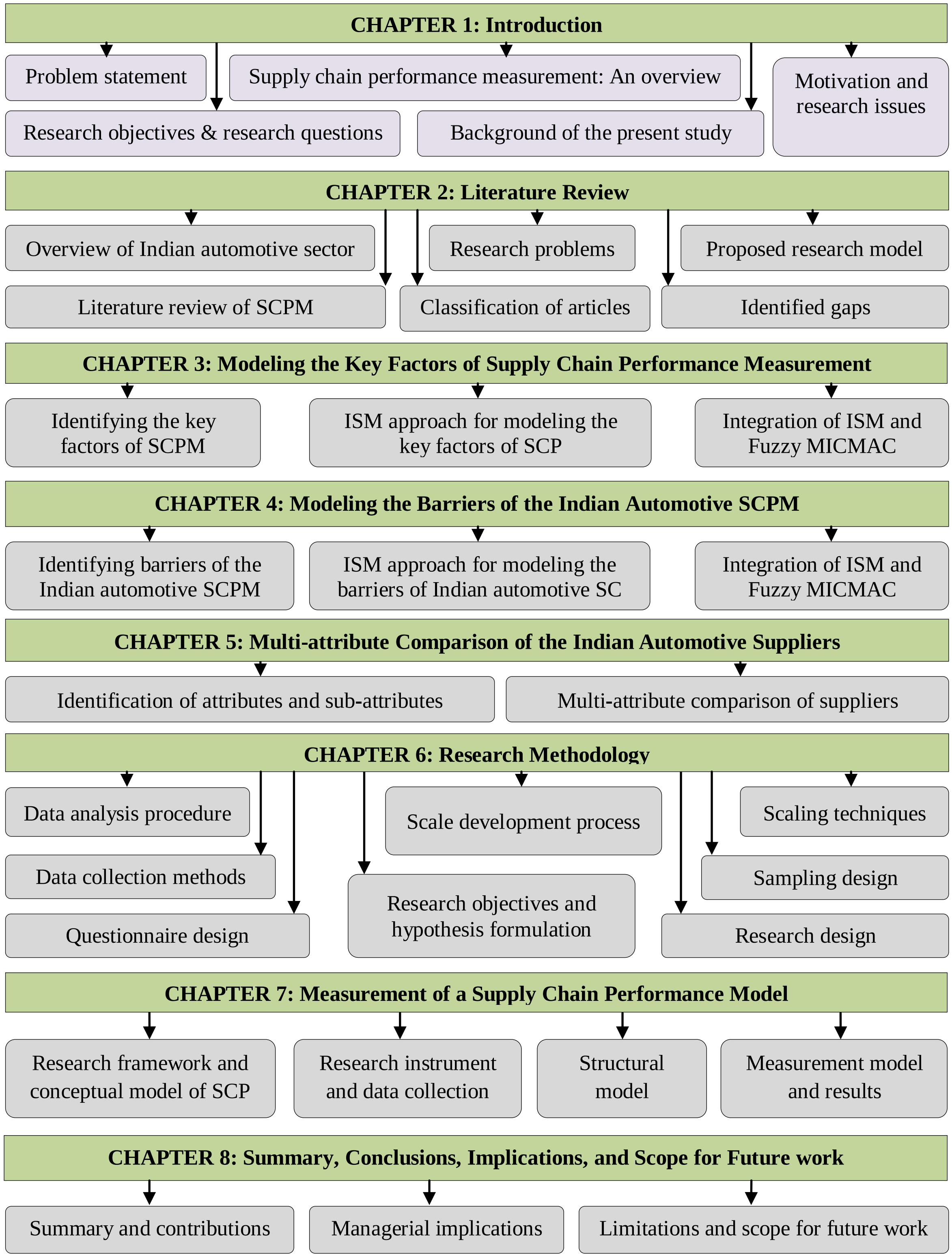

Figure 1.1: Thesis organization

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CHAPTER 2
Literature Review

Preview

This chapter presents a review of literature on supply chain management, supply chain performance measurement, barriers related to the Indian automotive industries, supplier selection/supplier evaluation and other related issues in this field of research. The present chapter includes various issues like key factors of supply chain performance measurement (SCPM), barriers of the Indian automotive industry, selection of the best supplier, research approach, and the possibility for future research and gaps. This review will also provide a strong foundation for conducting the present study and other areas that need to be explored.

2.1 Introduction

In the last few decades, supply chain management (SCM) concept has grown quickly. SCM concept is originated in the manufacturing sectors in the 1980s (Saad and Patel, 2006). Manufacturing sectors require more assets than service sectors. There is a very vast amount of research on SCPM in developed and developing countries and are many successful cases where SCM playing a significant role in improving the entire SC (Houlihan, 1985; Holti, 1997; Lee *et al.*, 2007). In last two decades, various researchers around the world have tried to measure the supply chain performance and developed some performances models. Therefore, the major challenge for SCM is to develop and improve the coordination's and continuously boost the overall supply chain performance (SCP). In the past few years, manufacturing organizations have invested in their suppliers to improve performance through developing long-term and secure relationships. Both academicians and practitioners understand the importance of supply chain management and performance measurement due to its highly transformation from a low-level concept to a high-level one. Some authors identify the need to measure supply chain performance but do not recommend any method for developing the metrics and fail to recognize the supply chain processes that drive entire firm's performance (Lambert and Pohlen, 2001). In fact, the lack of relevant performance key factors has been recognized as one of the major problems in management of a supply chain (Dreyer, 2000) and process management (Davenport *et al.*, 1996). These issues have attracted the attention of both practitioners and academicians who are exploring the concept of supply chain performance measurement (SCPM) as a solution to these challenges. These problems are becoming the core of strategy formulation in business organizations (Mebratu, 1998).

Some previous researchers have focused on major performance metrics (Beamon, 1999), categories of performance measures (Neely *et al.*, 1995), framework for measuring the strategic, tactical, and operational level (Gunasekaran *et al.*, 2001) supply chain performance related issues but there is a lack in study of interrelationship between the key factors of SCPM and developing a structural model to measure the overall SCP in the Indian automotive industry. Most of the Indian automotive firms are not implementing the different ideas of SCPM effectively. However, only few Indian automotive companies have effective strategies for SCPM. Therefore, it is imperative to develop a system for improving SCP. According to Saad and Patel (2006), still there is a dearth of studies in the context of the Indian automotive firms. Therefore, we have raised some issues on the Indian automotive firms' performances and given some important results and guidelines to the managers and researchers. Since, managers play an important role in the growth of the industry by adopting important key factors of SCPM and applying appropriate tools and techniques.

In the given context the main objective of this chapter is to provide an overview of the existing body of literature on constructs and their key factors of supply chain performance, barriers of the Indian automotive SC, and the relationship between the constructs and firm's overall SCP. In the further sections, overview of the Indian automotive sector, brief details of supply chain management, supply chain performance measurement, classification of articles, research methodologies, research gaps, research problems, research model, and need of the study are discussed. A taxonomical classification of literature is also provided to understand the growth of literature in this field of study.

2.2 Literature review at a glance

In the present study, an in-depth literature review gives an overview of SCPM, the association of SCPM constructs and firm's overall supply chain performance and research methodologies used in existing studies.

An extensive review of literature has been carried out to gain insights in the area of SCPM, the Indian automotive sector and research methodologies adopted in the present research. Accordingly, the literature is broadly classified into some main categories: (i) an overview of the Indian automotive sector (ii) supply chain management (iii) supply chain performance measurement (iv) classification of articles (v) review of research methodologies (vi) gaps identified from literature (vii) research problems (viii) proposed research model, and (ix) need of the study. These broad classifications were further sub classified according to the structure shown in Figure 2.1. Based on the findings of the literature review, a research model has been proposed for future research. This complete literature review provide an overview of the various aspects of supply chain performance to help both researchers and practitioners.

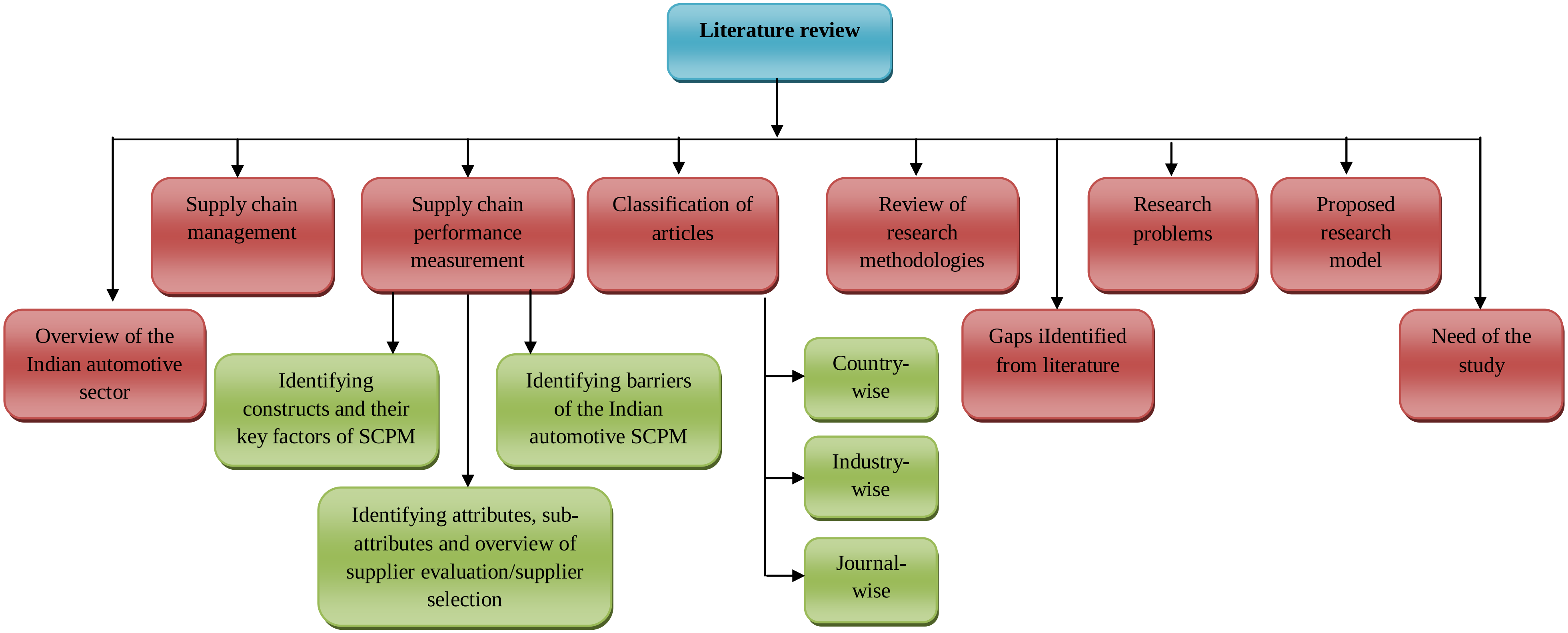

Figure 2.1: Overview of the literature review

2.3 Indian automotive sector: An overview

The Indian automotive industry came into being in the 1950s, and has grown-up since under a highly regulated and sheltered economic background (Saad and Patel, 2006; Joshi *et al.*, 2013). This industry started in the form of small and medium sized enterprises (SMEs). In other words, the history of Indian automotive industry is back about 50 years, when Hindustan Motors (HM) and Premier Automobiles Limited (PAL) were included with the particular objective of manufacturing components (Khare, 1997). In between 1950s to 1990s, Indian government considered about industrial development policy (Dangayach and Deshmukh, 2001). In the late-1980s and early-1990s, the Indian government deregulated entry into the automotive sector, dispensed with the use of licenses to control output levels, and considerably reduced import tariffs on auto components. Prior to 1990s, without a licence no single industry couraged to enter that highly protected segment of the auto organization (Khare, 1997). The Indian automotive organizations' SC is different and difficult from the western automotive SC. Here the word 'automotive industry' is used to include two wheelers, three wheelers, four wheelers (passenger cars), light commercial vehicles (LCVs), heavy commercial vehicles (HCVs), and auto parts manufacturers etc. After changing the policy of the Indian government, international auto assemblers entered into the Indian passenger car market. Nowadays, India is one of the world's best passenger car marketplaces and the second largest producer of two wheelers after China (Dangayach and Deshmukh, 2001; Joshi *et al.*, 2013). Therefore, automotive sector has important role in the Indian economy. It has been fastest growing sector in India and has more than 10% contribution in Indian Gross Domestic Product (GDP) (Joshi *et al.,* 2013). In 1996-97, the turnover of automotive industry was 4.55% of India's GDP. Moreover, the Indian manufacturing sector contributes 15% to the country's GDP (Indian Express, 2013). The Indian economoy has been growing very rapidly in recent years (Gill *et al*., 2010). According to an estimation contribution of Indian manufacturing sector in the country's GDP will be 25% by 2022 (Business Standard, 2013). This sector provides the jobs to the semi-skilled and uneducated workforce (Goyal, 2012). This fact is very important for the emerging economies like India where education level is very low. The Indian economy is growing at a better rate than many other countries (Deloitte, 2012). India is adopting a global approach to become an important player on an international platform. Indian automotive sector is the bitness of international players for example Suzuki, Mercedes, Honda, General Motors etc. and Yamah, Kawasaki, Honda etc. in four wheeler and two wheeler segments respectively.

According to Charan *et al.* (2009), Indian government is worried about the competitiveness of the manufacturing sector (National Manufacturing Competitiveness Council, Government of India, 2006). Presently, various multinational companies such as Honda, Mercedes, and Ford have set up their offices in India to supply for their universal operations. Such circulation led to the contribution of Indian automotive business in the worldwide SC activity. Competition among assemblers has become strong, and as a result organizations are increasingly being innovative in order to enhance quality, improve supply chain performance, reduce costs, and customers' demand. To get these targets, active organizations as well as new applicants are attempting to improve their SCs and implement lean production methods. As an example, after introducing the new automobile policy in 1993, India had facilitated the entry of global markets, which have brought with them innovative concepts.

2.4 Supply chain management (SCM)

Nowadays, SCM is a key strategic factor for increasing firms' effectiveness and better understanding of managerial goals like increased profitability and customer service. During the last two decades, SCM literature has grown quickly as a result of worldwide competition. The concept of SCM was originated in the manufacturing industries three decades before. Since the beginning of the manufacturing period, performance measures have been important for organizations as a way of obtaining knowledge about what is happening around them (Chibba, 2007). All members of the SC, both downstream and upstream, are actors who influence its output (e.g. cost, delivery, and quality) (Chibba, 2007). Worldwide interest in SCM has increased steadily since the 1980s (Sahay and Mohan, 2003). However, SCM is a quite new philosophy for academicians and practitioners. Chan (2003) proposed a process-based performance measurement system in which it is used to identify the performance and metrics. Process-based performance measurement does not only fit with the nature of SCM, but also contributes much more too continuous improvement of SCM. More and more Indian organizations today are realizing the importance of developing a comprehensive supply chain strategy and then linking this strategy to the overall business goals. However, there is still a lack of significant study of supply chain practices and its performance in developing countries like India (Austin, 1990). Development of the literature on SCPM can be divided into two different phases (Dixon *et al.*, 1990). Out of two phases, the first phase contributes to the period until the 1980s and concentrated on financial measures; the second phase, which starts in the late 1980s, communicates to the appearance of new SCM concepts. In other hand, the non-financial measures are crucial in measuring and improving the SCP.

The objective of this chapter is to provide the relevant literature of supply chain performance measurement in developing and developed nations based on the case of the Indian automotive sector. It also attempts to highlight the main key factors and inhibitors to the implementation of both concepts namely, SCM and performance measurement in India (Saad and Patel, 2006). As SCM focuses on process management beyond organizational boundaries, there is a need to measure performance for the effective management of a SC. Given definitions of supply chain management supports the bottom line concept of SC (see Table 2.1). Although there are various definitions given by different authors, but one thing is common in all definitions i.e. suppliers and customers. Because, any supply chain cannot think without suppliers and customers. A typical supply chain process is depicted in Figure 2.2. Figure 2.2 contains five levels (suppliers, manufacturers, distributors, retailers, and customers), where each level of the SC may contain numerous facilities.

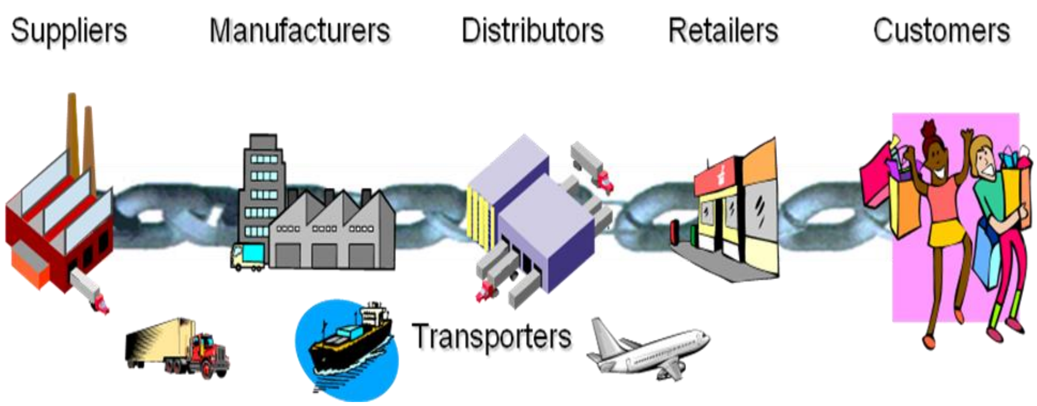

Figure 2.2: Supply chain process

Table 2.1: Definitions of supply chain management as reported in the literature

Author(s)	*Definition*
Christopher (1998)	"Defined as a network of connected and independent organizations mutually and cooperatively working together to control, manage, and improve the flow of materials and information from supplier to end user".
Chopra and Meindl (2001)	"Supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves".
Simchi Levi *et al.* (2004)	"SCM is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations and at the right time, in order to minimize system-wide costs while satisfying customers or service level requirements".

2.5 Supply chain performance measurement (SCPM)

Performance measurement is necessary to identify the seriousness of efforts towards a certain goal. Neely *et al.* (1995) defined performance measurement as the "*process of quantifying the effectiveness and efficiency of actions*.'' It provides guidelines for future improvement, sets benchmarks for others, and checks the efficiency and effectiveness of the steps taken to achieve the goal (Waggoner *et al.*, 1999). The need to measure the correct metrics of performance within an organization is vital, due to the fact that it may affect the decision process. Several studies highlight the need for the right type of performance measures in the SC (e.g. Nair and Narendran, 1997; Van Hoek, 1998; Beamon, 1999; Holmberg, 2000; Lai *et al.*, 2002; Lambert and Pohlen, 2001; Tracey and Tan, 2001; Basu, 2001; Christopher and Towill, 2001; Gunasekaran *et al.*, 2001; Van Hoek, 2001; Landeghem van and Persoons, 2001; Lambert and Pohlen, 2001; Otto and Kotzab, 2003; Petroni and Panciroli, 2002; Gunasekaran *et al.*, 2004; Morgan, 2004; Saad and Patel, 2006; Vereecke and Muylle, 2006; Shepherd and Gunter, 2006; Koh and Demirbag, 2007). These studies have attempted to outline and described different performance measures across and between organizations.

PM helps business management to identify excellent performance assists to make the tradeoffs between investment and profit (Neely *et al.*, 1994). Performance measurement and supply chain management problems are presently receiving significant practical and research agenda (Bai and Sarkis, 2012). Supply chain performance is an overall performance measure that depends on the performance of the SC phases. Neely *et al.* (1995) recognized some performance measurement approaches; criteria for measurement system design (Globerson, 1985); the performance measurement matrix (Keegan *et al.*, 1989), performance measurement questionnaires (Dixon *et al.*, 1990), and the balanced scorecard (Kaplan and Norton, 1992). Moreover, organizations are implementing various practices such as product quality, flexibility, operational performance, delivery performance, customer satisfaction, buyer-supplier relationship etc. to improve the organizations' performance. Therefore, companies are adopting latest technologies, new ideas, and strategies to highlight their efforts towards improving better SCP. The adoption of any new strategy and idea also raises the demand to measure the effectiveness and efficiency of that particular strategy and idea. Moreover, order lead time, buyer-supplier relationship, quality, on time delivery of goods, flexibility to meet particular customer needs are some of the key factors used to measure the SCP. In order to measure the improvements in supply chain performance, it is necessary to develop a measurement framework that is relevant, comprehensive, and feasible.

This thesis focuses on measuring the supply chain performance of Indian automotive industries, i.e. the constructs and their key factors/measures used to describe it. The performance of the supply chain has been widely covered in the literature. SCM is a long, complex and dynamic process. Development of the literature on performance measurements can be divided into two distinct phases (Dixon *et al.*, 1990). The first phase relates to the period until the 1980s and concentrated on financial measures such as profit, return on investment and productivity. The second phase, which commenced in the late-1980s, corresponds to the emergence of new management concepts such as SCM. Performance measurement has many uses, including the determination of the efficiency and effectiveness of an existing system. Overall, performance measurement is typically used to plan, design, implement, and monitor proposed systems. Performance measurement has recently expanded to the supply chain owing to the increased complexities of multiple processes and organisations that may be involved in product and service delivery and the role of supply chain relationships and processes in managing organisation strategic advantages (Gunasekaran *et al.* 2004, Bai and Sarkis, 2012). Table 2.2 describes the important definitions of supply chain performance/performance measurement. A taxonomical classification of literature review on supply chain performance measurement is provided in Table 2.11. In the next sub-sections, constructs and key factors of SCPM, barriers of the Indian automotive SCPM, and overview of supplier evaluation/supplier selection are described in brief.

Table 2.2: Definitions of SCP/performance measurement as reported in the literature

Author(s)	*Definition*
Van der Vorst (2000)	"Supply chain performance is the degree to which a supply chain fulfils end user requirements concerning the relevant performance indicators at any point in time and at what total supply chain cost".
Chopra and Meindl (2001)	"The performance of a supply chain can be defined by supply chain profitability, which has only one source of revenue: the customer".
Neely *et al.* (2005)	"Performance measurement as the process of quantifying the efficiency and effectiveness of past action".

2.5.1 Identifying constructs and their key factors of SCPM

In the one objective of this thesis, we have made an attempt to develop a scale and model to measure SCP of the Indian automotive industry. In another objective of this thesis, it was examined the interrelationship between the key factors of SCPM and developed an ISM-based model on the basis of those key factors. Therefore, supply chain performance measurement constructs/attributes, and key factors/sub-attributes were identified from the literature and with the help of experts' opinion. Definition of the constructs is shown in Table 2.3. Table 2.4 shows the list of the identified constructs and their key factors of SCPM. These constructs and key factors are discussed in more details in Chapter 7 and Chapter 3 respectively.

Table 2.3: Constructs/attributes of SCPM and their definitions

Constructs/Attributes	*Definition*
Plan (P)	Planning is the process that balance aggregate demand and supply to develop a course of action which best meets sourcing, production, and delivery requirements.
Source (S)	Sourcing is the process that procures goods and services to meet planned or actual demand.
Manufacturing (M)	Manufacturing is the process that transforms or produces product to a finished goods to meet particular customers need and demand.
Delivery (D)	Delivery is the process that provides finished goods and services to meet planned or actual demand typically including order, transportation, and distribution management.
Customer Service (CS)	Customer service is the process that associates with receiving or returning products from the buyers.

Table 2.4: Constructs/attributes and their key factors/sub-attributes references in the literature

Constructs/ Attributes	*References*	*Key factors/ Sub-attributes*	*References*
Plan (P)	Gunasekaran *et al.* (2001); Ren *et al.* (2004); Bhagwat and Sharma (2007); Dey and Cheffi (2013).	Order entry method (OEM)	Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007); Cho *et al.* (2012).
		Order lead-time (OLT)	Bower and Hout (1988); Christopher (1992); Towill (1997); Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007); Cho *et al.* (2012).
		Customer order path (COP)	Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007); Cho *et al.* (2012).
Source (S)	Ellram (1991); MacBeth and Ferguson (1994); De Toni *et al.* (1994); New (1996); Towill (1997); Fisher (1997); Braglia and Petroni (2000); Gunasekaran *et al.* (2001); Ghodsypour and O'Brien (2001); Choy *et al.* (2003a); Sarkar and Mohapatra (2006); Bhagwat and Sharma (2007); Keebler and Plank (2009); Aksoy and Ozturk (2011); Meena *et al.* (2011); Meena and Sarmah (2012); Viswanadham and Samvedi (2013); Meena and Sarmah (2013); Dey and Cheffi (2013); Bhattacharya *et al.* (2014).	Supplier selection (SS)	Ghodsypour and O'Brien (1998); Karpak *et al.* (1999); Braglia and Petroni (2000); Hong *et al.* (2005); Aksoy and Ozturk (2011); Meena *et al.* (2011); Meena and Sarmah (2013); Joshi *et al.* (2013).
		Purchase order cycle time (POCT)	Boer *et al.* (2001); Aksoy and Ozturk (2011).
		Buyer-supplier relationship (BSR)	Ellram (1991); De Toni *et al.* (1994); Towill (1997); Ghodsypour and O'Brien (2001); Johnston and Glark (2008); Rinehart et al. (2008); Lee *et al.* (2010); Aksoy and Ozturk (2011); Meena and Sarmah (2012); Joshi *et al.* (2013).
		Mutual assistance in solving problems (MASP)	Ellram (1991); MacBeth and Ferguson (1994); Landeros *et al.* (1995); New (1996); Maloni and Benton (1997); Doran *et al.* (2005); Thakkar *et al.* (2007); Cho *et al.* (2012); Joshi *et al.* (2013).
Manufacturing (M)	Skinner (1969); Hill (1987); Gerwin (1993); Slack *et al.* (1995); Mapes *et al.* (1997); De Toni and Tonchia (1998); Lambert and Pohlen (2001); Ren	Effectiveness of a master production schedule (EMPS)	Gunasekaran *et al.* (2001); Bhagwat and Sharma (2007); Robinson *et al.* (2008); Cho *et al.* (2012).
		Capacity utilization (CU)	Fitzgerald *et al.* (1991); Wild (1995); Slack *et al.* (1995); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007); Cho *et al.* (2012).

	et al. (2004); Benito and Benito (2005); Dangayach and Deshmukh (2006); Bhagwat and Sharma (2007); Chibba (2007); Lin *et al.* (2011); Viswanadham and Samvedi (2013).	Product cost (PC)	Stephen *et al.* (1993); Kekre *et al.* (1995); Beamon (1999); John *et al.* (2006).
		Quality (Q)	Hill (1987); Chandra and Sastry (1998); De Toni and Tonchia (1998); Dangayach and Deshmukh (2001).
		Flexibility (F)	Slack (1991); Das (1996); Beamon (1999); Robinson *et al.* (2008).
		Range of product and services (RPS)	Mapes *et al.* (1997); Fisher (1997); Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007).
Delivery (D)	Novich (1990); Gelders *et al.* (1994); Stewart (1995); Gunasekaran *et al.* (2001); Lambert and Pohlen (2001); Chibba (2007); Gunasekaran and Kobu (2007); Ganga and Carpinetti (2011); Pazhani *et al.* (2013); Viswanadham and Samvedi (2013).	Flexibility of delivery systems to meet particular customer needs (FDSMPCN)	Hill (1985); Novich (1990); Bhagwat and Sharma (2007); Cho *et al.* (2012).
		Effectiveness of delivery invoice methods (EDIM)	Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007).
		On time delivery of goods (OTDG)	Christopher (1992); Chao *et al.* (1993); Stewart (1995); Gunasekaran *et al.* (2004); Aksoy and Ozturk (2011).
		Delivery lead time (DLT)	Gelders *et al.* (1994); Stewart (1995); Gunasekaran *et al.* (2001); Shepherd and Gunter (2006).
Customer Service (CS)	Lee and Billington (1992); Van Hoek (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007); Gil *et al.* (2010); Meena and Sarmah (2012); Dey and Cheffi (2013).	Flexibility to meet particular customer needs (FMPCN)	Bower and Hout (1988); Stewart (1995); Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007); Pazhani *et al.* (2013).
		Post transaction measures of customer service (PTMCS)	Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bruhn and Georgi (2006); Shankar *et al.* (2006); Bhagwat and Sharma (2007); Cho *et al.* (2012).
		Customer query time (CQT)	Beamon (1999); Gunasekaran *et al.* (2001); Gunasekaran *et al.* (2004); Bhagwat and Sharma (2007).

2.5.2 Identifying barriers of the Indian automotive SCPM

The Indian automotive industries are facing several issues in SCPM due to various constraints. These constrains act like a barrier of SCPM. Therefore, we collected the literature and identified the different barriers that affect supply chain performance of the organization. Also, explored the relationship among the barriers of the Indian automotive SC and developed an ISM-based model. These barriers not only create problems in operations process but also influence each other's. Table 2.5 shows the list of the identified barriers with their sources. These barriers are discussed in more details in Chapter 4.

Table 2.5: Barriers and their sources in literature

S. No.	*Barriers*	*Sources*
1	Lack of awareness related to SCP measurement system	Klocek (2003); Wang *et al.* (2008); Charan *et al.* (2009).
2	Inadequate strategic planning	Bansal and Roth (2000); Wang *et al.* (2008); Mudgal *et al.* (2010); Joshi *et al.* (2013); Muduli *et al.* (2013).
3	Lack of top management dedication	Hamel and Prahalad (1989); Berry and Rondinelli, (1998); Aragon-Correa (1998); Van den Bosch and Van Riel (1998); Ravi and Shankar (2005); Zhu and Sarkis (2007); Kuo *et al.* (2009); Mudgal *et al.* (2010); Muduli *et al.* (2013).
4	Lack of trained manpower	Andrews-Speed (2004); Ravi and Shankar (2005); Wang *et al.* (2008).
5	Disinclination of the support from distributors, retailers and dealers	Foster and Muller (1990); Sarkar and Mohapatra (2006); Luthra *et al.* (2011); Kumar and Banerjee (2014).
6	Inefficient information and technology system	Rogers and Tibben-Lembke (1998); Zhihong (2004); Wang *et al.* (2008); Charan *et al.* (2009); Luthra *et al.* (2011).
7	Lack of appropriate implementation of SCP measurement system	Gunasekaran *et al.* (2004); Ren *et al.* (2004); Ravi and Shankar (2005); Saad and Patel (2006).
8	Encroaching market competition and uncertainty in demand	Yu Lin (2007); Hosseini (2007); Mudgal *et al.* (2010); Luthra *et al.* (2011).
9	Lack of appropriate production technology adoption	Gant (1996); Wang *et al.* (2008); Luthra *et al.* (2011).
10	Lack of support from government systems	Porter and van der Linde (1995); Scupola (2003); Gunasekaran *et al.* (2004); Singh *et al.* (2007); Mudgal *et al.* (2010); Joshi *et al.* (2013).
11	Lack of consistency in business capability between buyers and suppliers	Moberg *et al.* (2003); Welch and Wietfeldt (2005); Sarkar and Mohapatra (2006); Wang *et al.* (2008); Yu Lin and Hui Ho (2008); Meena and Sarmah (2012).
12	Dispersed IT infrastructure	Monczka and Morgan (1997); Bender (2000); Kilpatrick and Factor (2000); Shore and Venkatachalam (2003); Gunasekaran *et al.* (2004); Lohman *et al.* (2004); Singh *et al.* (2007); Mudgal *et al.* (2010); Joshi *et al.* (2013).
13	Lack of funding or financial constraints	Min and Galle (2001); Ravi and Shankar (2005); Jharkharia and Shankar (2006); Orsato (2006); Walker *et al.* (2008); Wang *et al.* (2008); Mudgal *et al.* (2010).

14	Destitute quality of human resource	Hillary (2000); Thompson (2002); Perron (2005); Yu Lin and Hui Ho (2008); Luthra *et al*. (2011); Mathiyazhagan (2013).

2.5.3 Identifying attributes, sub-attributes and overview of supplier selection

Nowadays, a supplier is the heart of any business performance development. For any business, a good supplier helps in the buying organization's future to reduce operational cost of the product. Organizations have learned about a single criterion for supplier selection is insufficient, now they have turned into more comprehensive multi-criteria decision making (MCDM) techniques. Therefore, selected vendors need to be evaluated on more than one criterion. This section focuses on supply chain performance attributes/constructs and sub-attributes/key factors of supply chain performance measurement (see Table 2.4). Therefore, supply chain performance attributes and sub-attributes were identified from the literature and with the help of experts' opinion after that used for supplier selection model. Supplier selection is an important activity in measuring the performance of a SC (Rao, 2002; Hutchins and Sutherland, 2008). A fuzzy AHP method was also suggested as a way to develop upon the supplier selection problem in the Indian automotive industry. Table 2.6 shows the related articles and their references on supplier selection/supplier evaluation; in which a fuzzy approach has been successfully applied.

Table 2.6: References of supplier selection and fuzzy approach

Article abstract	*References*
Proposed a simple flowchart for supplier evaluation.	Walton *et al*. (1998)
Proposed and demonstrated the application of data envelopment analysis (DEA) in evaluating the overall performance of suppliers in a manufacturing firm.	Liu *et al*. (2000)
Applied AHP to evaluate relative importance of criteria and assess the relative performance of suppliers.	Handfield *et al*. (2002)
Fuzzy number was introduced in the pair-wise comparison of AHP and an AHP based on fuzzy scales was proposed to determine the importance weights of customer requirements.	Kwong and Bai (2002)
Used fuzzy AHP to select the best supplier for a manufacturer firm in Turkey.	Kahraman *et al*. (2003)
Provided a fuzzy AHP tool to select the best catering firm providing the most customer satisfaction.	Kahraman *et al*. (2004)
Divided the supplier selection into two stages. Only ISO 14000 certification supplier can be involved in the next supplier selection process.	Chen (2005)
Vendor selection problem was treated as a fuzzy multi-objective integer programming vendor selection problem.	Kumar *et al*. (2006)
Proposed a hierarchical fuzzy system with supplier selection process.	Humphreys *et al*. (2006)
Used a multi-objective decision making process for evaluating suppliers' performance using fuzzy AHP.	Lu *et al*. (2007)
A multi-objective supplier selection model is developed under stochastic	Liao and Rittscher

demand conditions.	(2007)
Proposed integrated fuzzy multiple criteria decision making method and addressed the issue within the context of the vendor selection problem.	Yang *et al.* (2008)
Used fuzzy AHP method for supplier selection in high-tech industry.	Lee *et al.* (2009)
Proposed a new fuzzy-logic-based hybrid negotiation mechanism with suppliers and buyers for successful SCM and for a better solution.	Jain and Deshmukh (2009)
Proposed a structured model for evaluating and selecting the best third party reverse logistics provider by using fuzzy AHP.	Govindan (2009)
Presented a fuzzy technique for order preference by similarity to ideal solution (TOPSIS) approach for evaluating environmental performance of suppliers.	Awasthi *et al.* (2010)
Presented an example on solving the supplier selection problem in the apparel industry by using the AHP model.	Chan and Chan (2010)
Aided just-in-time (JIT) manufacturers in selecting the most appropriate suppliers and in evaluating supplier performance in automotive industry.	Aksoy and Ozturk (2011)
Explored the criteria that influence the performance of the automobile manufacturing industry, using the fuzzy set theory and decision making trial and evaluation laboratory (DEMATEL).	Lin *et al.* (2011)
Proposed a supply chain performance model based on fuzzy logic to predict performance based on causal relationships between metrics of the supply chain operations reference (SCOR) model.	Ganga and Carpinetti (2011)
Developed a benchmarking framework for cold chain performance and identified and prioritized potential alternatives for continuous improvement.	Joshi *et al.* (2011)
Introduced and proposed a new methodology for increasing the supplier selection and evaluated performance for selection of suppliers by using fuzzy AHP and fuzzy TOPSIS.	Zeydan *et al.* (2011)
Developed a framework of service supply chain performance measurement by fuzzy AHP method.	Cho *et al.* (2012)
Presented an integrated approach for selecting the appropriate supplier in the SC, using fuzzy AHP and fuzzy multi-objective linear programming.	Shaw *et al.* (2012)
Identified both performances-based and risk-based decision criteria using fuzzy AHP and fuzzy TOPSIS approach.	Viswanadham and Samvedi (2013)
Proposed a fuzzy multi-criteria approach for green suppliers' evaluation by using fuzzy set theory and TOPSIS in automobile industry.	Shen *et al.* (2013)
Proposed a novel fuzzy multiple attribute decision making (MADM) model for solving truck selection problem.	Baykasoglu *et al.* (2013)
Utilized the DEMATEL approach to recognize the influential criteria of carbon management in GSC for improving the overall performance of suppliers.	Hsu *et al.* (2013)
Introduced a comprehensive environment friendly approach for supplier selection in automobile industry in India.	Kumar *et al.* (2014)

2.6 Classification of articles

The main objective of this section is to address the depth of literature in the field of supply chain performance (SCP) and performance measurement. The increasing number of studies in this field made this important to identify the growth of literature as well as to identify the possible region of research. That is why; we have presented the bibliographic scheme of supply chain performance and performance measurement related literature. The main reason to adopt this classification scheme is dual. First, is to provide the status of existing literature in this field; second, is to draw attention of researchers to the possible untapped areas by providing a future agenda for research. This classification will also help future researchers and practitioners to know the possible future research and growth of the industries. One of the important issues in the selection of literature, reports and publication of various consultancy firms, working papers, textbooks, master and doctoral dissertations and government reports also contain literature related to SCP and available in abundance. According to Ngai (2005), maximum number of people including both practitioner and academician use journals to collect the information. Therefore none of them was selected for this review purpose. The publications/journals to collect literature were confined to the following online databases:

- ABI/Inform Complete
- Emerald Full Text
- EBSCOS Business Source Premier
- Elsevier’s ScienceDirect
- John Wiley Publications
- Sage Publications
- Springer
- Taylor & Francis
- Google Scholar

Content analysis is defined as “the objective, systematic, and quantitative description of the manifest content of a communication” (Malhotra and Dash, 2009). It is an important tool that is primarily based on identifying the availability of information in various disciplines. To select papers for the literature review, we included leading journals such as supply chain management, performance measurement, and performance assessment. Various keywords were used in literature search from above mentioned sources. These include “supply chain”, “supply chain performance” together with “measurement”, “evaluation”, “measures” and “metrics”. Paper search with the help of these keywords from all databases is based on the keyword detected in the title, abstract, keyword list and, in full text. The study of various research papers after this extensive search came out with lots of article but we selected only those articles which were important or related to solve the purpose of this study. These papers have been tabulated for further classification. Most of the excluded papers were talking about supply chain in different contexts like country, methodology etc. and were not found suitable for this study.

After the selection of papers, full paper was thoroughly studied for further categorization. Analysis of literature is based on various criteria. All important 100 papers were classified into the following three time periods of publication. Excepting these 100 articles, other related papers on supply chain performance and based on adopted methodologies were also studied and considered time to time for this study. The main reason of this distribution was to help in the longitudinal study of supply chain performance literature. These articles were analyzed on the basis of different criteria.

i) Period I: 1999-2003
ii) Period II: 2004-2008
iii) Period III: 2009-2014

2.6.1 Classification of articles in terms of country

Country-wise classification of literature is very crucial to identify the importance of the research for this critical issue across the globe (Goyal *et al.*, 2013). Future research could be focused on the untapped part of the area to sensitize the issue of supply chain performance measurement. During the period of 2009-2014, maximum number of articles related to the issues and methodologies on supply chain performance, performance measurement, ISM, fuzzy AHP, and SEM were published as shown in Table 2.7. During the period of 1999-2003, only 22 articles were published on the above mentioned issues. For this study, we have taken approx. 33% articles of the Indian authors.

Table 2.7: Country-wise distribution

Time Interval/ → *Country ↓*	*1999-2003*	*2004-2008*	*2009-2014*	*Total*
Australia	---	2	1	*3*
Canada	---	---	2	*2*
China	---	1	3	*4*
Finland	---	1	---	*1*
France	---	---	1	*1*
Germany	1	---	1	*2*
Hong Kong	3	3	---	*6*
India	3	13	17	*33*
Iran	---	---	2	*2*
Ireland	---	2	---	*2*
Italy	1	1	1	*3*
Korea	1	1	2	*4*
Malaysia	---	---	1	*1*

Netherlands	1	---	---	*1*
Qatar	---	---	1	*1*
Singapore	---	2	---	*2*
Taiwan	---	---	2	*2*
Turkey	---	---	4	*4*
UK	3	5	3	*11*
USA	9	5	1	*15*
Total	*22*	*36*	*42*	*100*

2.6.2 Classification of articles in terms of industry

In the distribution of articles in terms of industry it is found that most of the articles published on the supply chain performance measurement are related to the automotive/automobile industries. Out of 100 articles, only 50 articles used industry based study. Table 2.8 shows that among those 50 articles, 23 articles are related to the Indian automotive industry. Maximum numbers of studies fall under the category of 'automotive/automobile industry'. Distribution of articles on the basis of industry-wise clearly depicts that in the time period of 1999-2003, number of published articles were less compare to the 2009-2014. However, there is a sharp growth of research in this area of late.

Table 2.8: Industry-wise distribution

Time Interval/ → *Industry ↓*	*1999-2003*	*2004-2008*	*2009-2014*	*Total*
Airlines	---	1	---	*1*
Automotive/Automobile	4	7	12	*23*
Banking	---	---	1	*1*
Carpet	---	---	1	*1*
Chemical	---	---	1	*1*
Computer Hardware	---	1	---	*1*
Electronics/Telecommunications	2	4	---	*6*
Food	---	---	1	*1*
Hotel	---	---	1	*1*
Mining	---	---	1	*1*
Postal	---	1	---	*1*
Public Sector	---	---	1	*1*
Pulp & Paper	---	1	1	*2*
Retail	---	---	3	*3*
Service	---	2	---	*2*
Transportation/Logistics	3	1	---	*4*
Total	*9*	*18*	*23*	*50*

2.6.3 Classification of articles in terms of journals

Articles related to supply chain performance measurement are widely published in various reputed journals in earlier mentioned databases. There are in total 47 journals that published papers related to the issue studied in the given time frame. Maximum numbers of papers are published in *International Journal of Production Economics* (9); which is followed by *International Journal of Operations & Production Management* (6), *Experts Systems with Applications* (5), *International Journal of Productivity and Performance Management* (5), and *International Journal of Production Research* (5). The list of journals along with the number of articles is shown in the Table 2.9.

Table 2.9: Journal-wise distribution

Journal Name	*No. of Articles*
Asia Pacific Journal of Marketing and Logistics	2
Benchmarking: An International Journal	5
Business Process Management Journal	3
Computers & Industrial Engineering	4
Computers in Industry	2
Decision Sciences	1
Decision Support Systems	1
European Journal of Operational Research	1
European Journal of Purchasing & Supply Management	2
Expert Systems with Applications	5
Facilities	1
Industrial Management & Data Systems	1
Industrial Marketing Management	1
Int. J. Production Economics	1
Integrated Manufacturing Systems	1
International Journal of Advanced Manufacturing Technology	1
International Journal of Business, Management and Social Sciences	1
International Journal of Logistics Systems and Management	1
International Journal of Operations & Production Management	6
International Journal of Physical Distribution & Logistics Management	1
International Journal of Production Economics	9
International Journal of Production Research	5
International Journal of Productivity and Performance Management	5
International Review of Business Research Papers	1
Journal of Business Logistics	1
Journal of Cleaner Production	1
Journal of Engineering and Technology Management	1
Journal of Manufacturing Systems	2
Journal of Manufacturing Technology Management	1
Journal of Operations Management	4
Journal of Purchasing & Supply Management	3
Journal of the Operational Research Society	1
Management Decision	1

Management of Environmental Quality: An International Journal	1
MIT Sloan Management Review	1
Omega: The International Journal of Management Science	3
Production Planning and Control	2
Research Policy	2
Resources, Conservation and Recycling	2
Social and Behavioral Sciences	2
Software Quality Journal	1
Supply Chain Management: An International Journal	3
Technological Forecasting & Social Change	1
Technovation	1
The International Journal of Logistics Management	2
The IUP Journal of Operations Management	1
Transportation Research Part E	2
Total	*100*

2.7 Review of research methodologies

Earlier, various scholars and researchers have used various methodologies in the field of supply chain performance measurement. On the basis of the gaps and importance highlighted in the thesis earlier of, various tools and techniques have been identified and applied in the present research. A detail of interpretive structural modeling (ISM) technique has been provided in the Section 3.3 of Chapter 3 and Section 4.3 of the Chapter 4. ISM technique has some advantages like, it incorporates experts' subjective judgments and their knowledge base in a most systematic manner and provides plenty opportunity for revision of judgments (Thakkar *et al.*, 2008). Further, the detail of fuzzy analytic hierarchy process (fuzzy AHP) method has been given in the Section 5.3 of Chapter 5. Fuzzy AHP method is robust and easy to use decisional method and measures the relative importance of a given variable on a ratio scale (Meade and Presley, 2002). Finally, some other tools and techniques such as SPSS 19.0 and SmartPLS Version 2.0 M3 softwares have been used to test the reliability, convergent and discriminant validity, and validity of the scale for structural equation modeling (SEM) in the Chapter 6 and Chapter 7. The advantages of exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are; EFA is used in data reduction strategy and useful when the numbers of factors are not known and moreover when it is uncertain that which factor will load on which constructs or attributes, and CFA has the ability to quantitatively assess the constructs validity of a measurement model, there is no need to have large sample while applying CFA by using SmartPLS (Chin *et al.*, 2003). Before applying all these tools and techniques, a questionnaire was developed and data were collected from various automotive companies in India. The main advantages of questionnaire based survey are; information can be collected from a large group of people, possible to maintain the confidentiality of the respondents (Akbayrak, 2000), it is relatively an easy method for collection of data (Malhotra and Dash, 2009).

2.8 Gaps identified from literature

There are various studies available in the literature on supply chain performance, and performance measurement. However, these studies have some research gaps and have been included as an objective of this thesis. Based on the outcome of this review, possibilities for future research could be categorized on the basis of following guidelines.

More research is needed to develop supply chain performance metrics and to overcome the implementation of barriers (Lambert and Pohlen, 2001). They also revealed that most of the literature has focused on analyzing and categorizing performance measurement systems but little research has been devoted to SCPM. Therefore, quantification of efforts towards measuring the supply chain performance or increasing the organization's performance is the need of the hour. In addition, the effectiveness of appropriate key measures of supply chain performance or selection of performance measures (Charan *et al.*, 2008; Kurien and Qureshi, 2011; Bai and Sarkis, 2012) and barriers of the Indian automotive supply chain (Ravi and Shankar, 2005; Charan *et al.*, 2009; Keebler and Plank, 2009) are still lacking the descriptive research (Gunasekaran et al, 2001; Chan and Qi, 2003; Saad and Patel, 2006; Kim, 2007; Cai *et al.*, 2009; Akyuz and Erkan, 2010; Cuthbertson and Piotrowicz, 2011; Cho *et al.,* 2012).

One gap is found on supply chain performance measurement across different countries (Cuthbertson and Piotrowicz, 2011; Cho *et al.*, 2012; Dey and Cheffi, 2013). An effective and working performance measurement system is required for implementation and also need attention for updating performance measures once they have been implemented (Neely *et al.*, 1994, Christopher, 1998; Beamon, 1999; Lambert and Pohlen, 2001; Gunasekaran *et al.*, 2001, Lohman *et al.*, 2004; Van der Vorst, 2005; Chai *et al.*, 2009; Akyuz and Erkan, 2010; Kurien and Qureshi, 2011; Bai and Sarkis, 2012). Lambert and Pohlen (2001) directed that there is a critical issue in measuring the supply chain performance such as the lack of performance key indicators for measuring across the overall SC (Aramyan, 2007; Chibba, 2007). Keebler and Plank (2009) also highlighted in their study about the enablers and barriers of supply chain performance measurement as are the future research arenas. Another research gap focused on empirical study to investigate supplier selection on the basis of suppliers' evaluations and performance in a specific industry (Bahinipati *et al.*, 2009; Zeydan *et al.*, 2011; Viswanadham and Samvedi, 2013; Shen *et* *al.*, 2013). According to Charan *et al.* (2008), there is a need to test the hypothetical models of supply chain performance measurement through structural equation modeling (SEM) approach. One more important issue is that most of the research on supply chain performance and selected industry were often focused on the developed countries. Therefore, the present study aims to develop an integrated scale to measure the supply chain performance, as well as to assess the impact of supply chain performance measurement constructs on overall supply chain performance in context of the Indian automotive sectors.

Several relevant issues and application area have been discussed in the present chapter but still there are certain gaps in the literature. This section aimed to discuss the present research scenario of the factors of supply chain performance measurement and its impact on firm's supply chain performance in the Indian automotive sectors. In spite of the existing quality of research in this area; there is plenty of scope to explore this relationship. More number of studies of this organization in a different perspective is necessary to reach more reliable and conclusive results. Literature shows that only few numbers of studies on above discussed issues/topics have been accomplished in this country. To bridge these gaps, this study is carried out for the measurement of supply chain performance of the Indian automotive industries. The research gap are identified and presented in Table 2.10.

2.9 Research problems

As discussed in an earlier section of this chapter, there is a significant growth of research looking at the impact of supply chain performance measurement constructs and their key factors on firm's overall supply chain performance. The number of studies has been conducted on this topic. The Indian automotive organizations' SC is different and difficult from the western automotive SC. In the present era of globalization, India is one of the world's best passenger car market place and the second largest producer of two wheelers. After changing the policy of the Indian government, international auto assemblers entered into the Indian passenger car market. Moreover, India is adopting a global approach to become an important player on an international platform. Earlier literature raises the need to study this relationship in context of the Indian automotive industry. Therefore, Indian automotive industries need to study the results of their efforts towards firm's performance measurement. The main objective of this study is to measure the impact of SCPM constructs on firm's overall supply chain performance in the Indian automotive industry.

Table 2.10: Gaps identified from literature

Author	*Objective*	*Methodology*	*Gaps*
Shen *et al.* (2013)	To examine GSCM to propose a fuzzy multi-criteria approach for green suppliers' evaluation.	Fuzzy Set Theory	Future research should conduct an empirical study to investigate supplier selection in a specific industry.
Joshi *et al.* (2013)	To examine the determinants of competitiveness for Indian automotive industry, in special context to its supply chain performance indicators.	Case Study	More case studies can be conducted by considering the multiple Indian automotive component manufacturing companies that have different size and level of competitiveness. Further, results can be compared for developed and developing countries.
Viswanadham and Samvedi (2013)	To identify both performances-based and risk-based decision criteria, which are important and critical to the SC.	Fuzzy AHP	Multi-tier supplier selection is being pursued in recent times and fuzzy AHP and fuzzy TOPSIS method can be extended to this case.
Cho *et al.* (2012)	To evolve an efficient and effective service supply chain and to develop a framework of service SCPM.	Fuzzy AHP	Both academic research and practitioner are required to develop new measures and new programs for evaluating the performance of the service supply chain.
Bai and Sarkis (2012)	To introduce a novel application of neighbourhood rough-set theory for the identification and selection of performance measures for an organization.	SCOR Model	An effective and working PMS is required for implementation of this technique. There is also need much attention for updating performance measures once they have been implemented.
Cuthbertson and Piotrowicz (2011)	To propose a common framework for the empirical analysis of supply chain performance measurement systems used in different supply chain contexts.	Case Study	Further empirical research is required to fully appreciate the breadth of application of this framework. There is also an opportunity to analyse how selected companies within supply chains measure their performance.
Zeydan *et al.* (2011)	To introduce new methodology and propose for increasing the supplier selection and evaluate performance for selection of suppliers.	Fuzzy AHP	Qualitative and quantitative outputs are not the exact decision making tools alone and it can be further analysis.
Kurien and Qureshi (2011)	To review the literature of performance measurement for supply chains.	Review the Literature, Case Study	There is a need for further research in the area of SCPM system.
Cai *et al.* (2011)	To investigate the effects of cooperative norms on supplier	SEM	Future research may need to conduct longitudinal studies to further examine the relationships among the three constructs at

	performance.		different stages of the evolving buyer-supplier relationship. Also, research needs to follow more rigorous procedures to reduce concern of common method variance and to increase the validity of the measures.
Akyuz and Erkan (2010)	To provide a critical review on supply chain performance measurement and also reveals the basic research methodologies.	Questionnaire Based Survey	There is a need of more research and is still an open area of research on supply chain performance measurement. Also there is a need for the development of a framework and empirical testing of the performance measures and metrics for cross-industry also.
Awasthi *et al.* (2010)	To present a fuzzy multi-criteria approach for evaluating environmental performance of suppliers.	Fuzzy TOPSIS	This approach can be practically applied in evaluating environmental performance of suppliers.
Faisal (2010)	To present an approach to effectively adapt sustainable practices in a supply chain by understanding the dynamics between various enablers.	ISM	Graph theoretic approach can be applied to develop a quantitative measure of these enablers. Further, analysis of moment structures (AMOS) software can be used to test the validity of developed model.
Charan *et al.* (2009)	To determine the key barriers of supply chain performance measurement system implementation.	ISM	SEM approach can be applied in the future research to test the validity of this model.
Keebler and Plank (2009)	To describe the state of logistics performance measurement.	Delphi Technique	The notion of enablers and barriers is a very important research arena.
Cai *et al.* (2009)	To propose a framework using a systematic approach to improving the iterative key performance indicators accomplishment in a supply chain context.	Systematic Approach	There is a gap between application and research in supply chain performance measurement and improvement.
Sodhi and Son (2009)	To model the strategic as well as the operational dimension of performance of supplier–retailer partnerships.	Regression Analysis	Future research could also study the relationships between the five factors themselves using SEM by using a larger sample.
Charan *et al.* (2008)	To determine the key supply chain performance measurement system implementation variables.	ISM	SEM approach can be applied to test the validity of such hypothetical models.
Thakkar *et al.* (2008)	To review the literature on supply chain management practices in SMEs.	Literature Based Research	Outlined propositions and theoretical constructs can be made more precise and focused from continued and cross-sectoral studies.
Slobodow *et al.*	To analyze the buyer-supplier	Two-Way	There is a need of buyer-supplier relationships and a good

(2008)	relationship and about the prior literature of measuring supplier and buyer performance.	Scorecard	communication. Also, there is a need to develop a supply chain metrics for buyers and also require to improve more research on the concepts of dual accountability and the Two-Way Scorecard.
Qureshi *et al.* (2007)	To model the key variables of logistics outsourcing relationship between shippers and logistics service providers.	ISM	SEM may be applied to test the validity of such hypothetical model. Statistical software like Amos. can be used in future to build correlation matrix and confirmatory factor analysis to validate the relationship.
Saad and Patel (2006)	To investigate the relevance of the concept of supply chain performance and identify performance measures sets for SCP.	Qualitative and Quantitative Methods, Factor Analysis	The Indian automotive sector is not embracing the whole philosophy of supply chain performance. This can be interpreted as either a lack of proper understanding of the concept or an interesting attempt to adapt the concept to the Indian context and culture.
Ravi and Shankar (2005)	To analyze the interaction among the major barriers.	ISM	SEM technique can be applied to test the validity of this model in future.
Gunasekaran *et al.* (2004)	To develop a framework to promote a better understanding of the importance of SCM performance measurement and metrics.	Empirical Analysis	Industry consortiums, consultants, and researchers could be helpful in promoting SCM performance measurement generally, and in developing measures and measurement techniques specifically.
Humphreys *et al.* (2004)	To examine the role of supplier development in the context of buyer–supplier performance from a buying firm's perspective.	Factor Analysis, Regression Analysis	Further research is needed to corroborate these findings with larger and more representative samples and to investigate supplier development activities in other industrial sectors.
Schmitz and Platts (2003)	To develop a conceptual framework describing the roles of supplier performance measurement.	Qualitative and Case Study	Future studies should aim to, first, take into considerations the suppliers' perspective on the evaluation process, and second, include a broader view of supplier evaluation. And future studies addressed, how does performance measurement affect the buyer-supplier relationship?
Chan and Qi (2003)	To propose a process-based approach to mapping and analyzing the practically complex supply chain network and to identify the performance and metrics	Performance of Activity Approach	There is a need of a suitable approach to aggregating the existing or new performance measures into the holistic, integrated system in order to assess the SC. This study also identifies the gap for future research in performance measurement of SCM.
Frohlich (2002)	To address the questions using data from a large single nation study.	SEM	Provided reliable and valid scales for measuring upstream supplier and downstream customer e-integration can facilitate

			future work in this area and should prove valuable to other SC researchers.
Lai *et al.* (2002)	To investigate the construct of, and develop a measurement instrument for, supply chain performance (SCP) in transport logistics.	CFA	Future research can also focus more on the relationship between SCP in transport logistics and other constructs, such as competitive advantage. There is a need to extend the study of SCP to other logistics contexts in the SC.
Gunasekaran *et al.* (2001)	To develop a framework for measuring the strategic, tactical and operational level performance in a supply chain.	Literature Survey	A lack of balanced approach between financial and non-financial performance measures and the study can be done on the performance measures for the complete SC. To bridging the gap between the need for a model with which performance of a SC can be assessed, and the potential areas of improvement that can be identified.
Brewer and Speh (2000)	To discuss the concept of SCM and the limitations of traditional logistics performance measures and provides an overview of balanced scorecard performance measurement systems.	Balanced Scorecard	Future challenge for managers are to craft additional metrics that focus on key supply chain process and interactions.
Beamon (1999)	To present a framework for the selection of performance measurement systems for manufacturing supply chains.	Quantitative Approach	There is an ever-increasing number of supply chain models presented in literature, there is very little available in SCP measure selection.

2.10 Proposed research model

On the basis of various studies and the gaps identified from the literature, a research model has been proposed and shown in Figure 2.3. In this proposed model, 5 constructs and their 20 key factors are presented for measuring the overall supply chain performance of a firm. Firm's overall supply chain performance is classified on four factors i.e. Information carrying cost, manufacturing cost, flexibility of service system to meet customer needs, and total inventory cost.

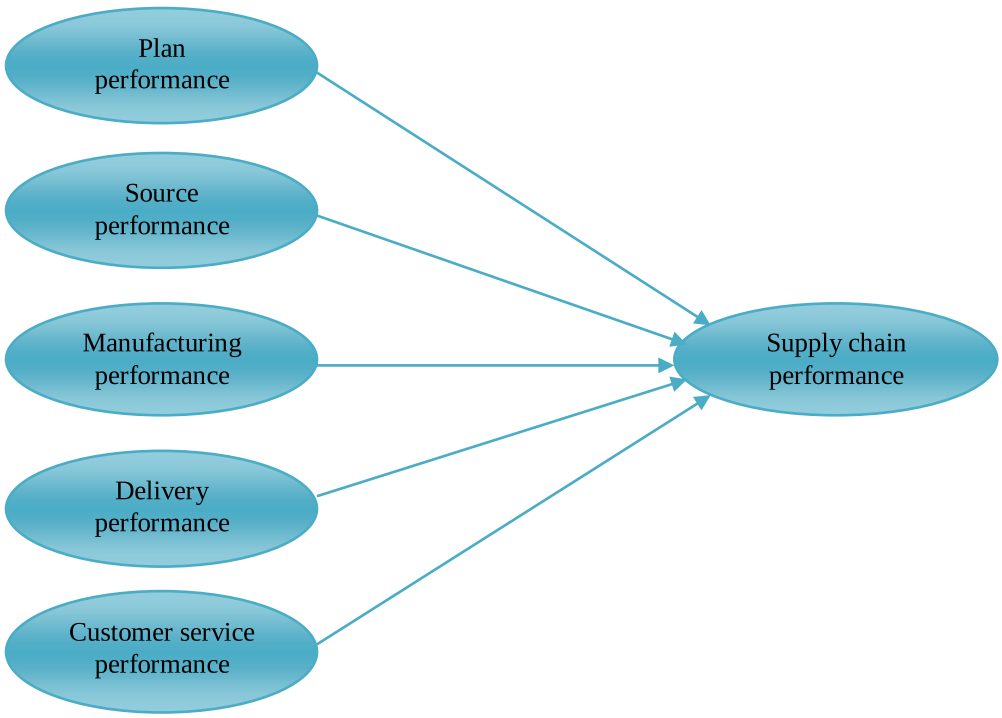

Figure 2.3: Proposed research model

2.11 Need of the study

SCM plays an important role in any business processes for increasing the performance of a firm. In the current business scenario, measuring and increasing the supply chain performance of a firm is a big issue. Nowadays, one of the major challenges before the top management is to develop appropriate measures for SCPM in the Indian automotive industry. In last two decades, various researchers around the world have tried to measure the supply chain performance and developed some performance models. Various authors found that the Indian automotive industries are not implementing the important concepts of SCM properly. Most of the Indian automotive firms are not implementing the different ideas of SCPM effectively. However, only few Indian automotive firms have effective strategies for SCPM. These issues remain untapped and still there is a lack of studies in context of the Indian automotive firms (Saad and Patel; 2006). Therefore, these problems are motivating to undertake supply chain performance issues with the objective of increasing business performance of SC activities. Very few studies are available in the literature in context of the Indian automotive firms (e.g. Garg and Deshmukh, 2010; Kumar and Subrahmanya, 2010; Charan *et al.*, 2009; Saad and Patel, 2006; Ravi and Shankar, 2005). In this context, performance measurement is an essential tool for industries to improve efficiency and effectiveness of SC (Beamon, 1999; Shepherd and Gunter, 2006).

From the last two decades, the concept of supply chain performance is offering both challenges and opportunities for manufacturing sectors. Now efforts are required to develop effective supply chain performance measurement system in the business organization. Literature shows the dearth of a scale which can measure the organization's entire supply chain performance in the developing countries like India.

Further, the study of relationship between SCPM constructs and firm's SCP is very important. Moreover, the assessment of supply chain performance measurement constructs and its impact on firm's overall supply chain performance has been identified as an important issue that needs to be studied. In the present study, attempt of author is to refine this relation in context of the developing countries like India. In addition, review of literature shows an important gap, that very few studies have assessed the interrelationships among the key factors of SCPM and barriers of the Indian automotive SC and the impact of SCPM constructs on firm's overall supply chain performance in developing countries like India. Furthermore, these studies are focused on one dimension of supply chain performance measurement. Therefore, by development of an integrated scale of supply chain performance measurement and its impact on organization performance is need of the hour.

Table 2.11: Literature review of supply chain performance measurement

Author(s)/Year / Journal	*Industry/ Country*	*Objective(s)*	*Instrument/ Methodology*	*Results/ Findings*	*Future Scope/ Research Gaps*
Bhattacharya *et al.*/ 2014/ Production Planning and Control	Carpet Manufacturing / UK	To delineate a green supply chain performance measurement framework using an intra-organisational collaborative decision-making approach.	Fuzzy analytic network process (Fuzzy ANP), Case Study	Internal operations are dependent on suppliers' activities. The outcome of environmental initiatives and the level of integration of the SC may encourage managers to pay more attention to audit and performance thereby improving overall GSC performance.	Future research could include implementation of the case with a more efficient CDM approach such as integrated fuzzy multi-criteria planning tool combining quality function deployment and ANP.
Shen *et al.*/ 2013 Resources, Conservation and Recycling	Automobile / Iran	To examine GSCM to propose a fuzzy multi-criteria approach for green suppliers' evaluation.	Fuzzy Set Theory, TOPSIS	Results showed that the final decision is insensitive to the attributes that are used in the evaluation process.	Future research should conduct an empirical study to investigate supplier selection in a specific industry.
Joshi *et al.*/ 2013/ Int. J. Production Economics	Automotive / India	To examine the determinants of competitiveness for Indian automotive industry, in special context to its supply chain performance indicators.	Case Study, ANP	Business environmental factors such as workers' skills, globalization, and government regulations contribute the most to the overall supply chain competitiveness of the IAC.	More case studies can be conducted by considering the multiple Indian automotive component manufacturing companies that have different size and level of competitiveness. Further, results can be compared for developed and developing countries.
Vinodh *et al.*/ 2013/ Journal of Manufacturing Systems	Automotive / India	To assess the agile manufacturing performance, an agile supply chain model is to develop.	Fuzzy Logic, Case Study	A unique feature of this ASC assessment model is that it is incorporated with fuzzy logic approach which enables the use of linguistic terms to assess the performance of ASC attributes.	In future, numerous case studies could be carried out in different organizations across varied sectors to further enhance and refinethe developed SC agility assessment model.
Muduli *et al.*/	Mining	To explore various	ISM	An understanding of the	Future work to quantify the impact

2013/ Resources, Conservation and Recycling	/ India	behavioural factors affecting GCSM practices and their interactions which help to attain green-enabled needs.		behavioural factors that affect the willingness and ultimately the effectiveness of human resources in the GSCM environment assumes importance. Top Management Support' is identified as the key behavioural factor that drives other factors.	of each behavioural factor may pursue a graphic theoretic and matrix approach. In the future, structural equation modeling (SEM) can be used to test the validity of this model.
Estampe *et al.*/ 2013/ Int. J. Production Economics	France	To analyze various models used to assess supply chains by highlighting their specific characteristics and applicability in different contexts.		It suggested a table displaying various performance evaluation models organised by the model's origin, the type of analysis used, relevant conditions and constraints, the degree of conceptualisation and the indicators being devised.	These future research paths will very probably be able to generate new evaluation models capable of integrating new ways of creating value for the whole of the supply chain.
Viswanadham and Samvedi/ 2013/ International Journal of Production Research	India	To identify both performances-based and risk-based decision criteria, which are important and critical to the SC.	Fuzzy AHP, Fuzzy TOPSIS	The resulting consolidated scores provide an opportunity to the supply chain managers to select a better supplier.	Multi-tier supplier selection is being pursued in recent times and fuzzy AHP and fuzzy TOPSIS method can be extended to this case.
Dey and Cheffi/ 2013/ Production Planning and Control	Automotive / UK	To develop and deploy an analytical framework for measuring the environmental performance of manufacturing SCs.	AHP	Theoretically it contributes holistic constructs for designing a GSC and managing it for sustainability; and practically it helps industry practitioners to measure and improve the environmental performance of their SC. AHP is a suitable approach for reaching a consensus in controversial decisions.	Further research avenue could involve studying GSC performance measurement across different countries.
Vaidya and Hudnurkar/ 2013/ International	Chemical / India	To propose an approach to evaluate the performance of supply chain using multiple	AHP, Case Study	The proposed method provides a holistic view of analyzing performance of the supply chain and also helps rank the various	This link-based approach can be suitably modified to suit the other supply-chain structures such as assembly, divergent and general.

Journal of Productivity and Performance Management		criteria.		links according to its performance.	
Cho *et al.*/ 2012/ Computers & Industrial Engineering	Hotel Industry / Korea	To evolve an efficient and effective service supply chain and to develop a framework of service SCPM.	Fuzzy AHP	This service supply chain performance measurement framework is the beneficial to researchers and practicing managers in identification of opportunities for improvements in service supply chain.	Both academic research and practitioner are required to develop new measures and new programs for evaluating the performance of the service supply chain.
Bai and Sarkis/ 2012/ International Journal of Production Research	China	To introduce a novel application of neighbourhood rough-set theory for the identification and selection of performance measures for an organization.	SCOR Model, Rough-Set Theory	The identification and development of sourcing performance measurement using the SCOR database show good applicability to logistics and supply-chain sourcing functions.	An effective and working PMS is required for implementation of this technique. There is also need much attention for updating performance measures once they have been implemented.
Uysal/ 2012/ Social and Behavioral Sciences	Manufacturing / Turkey	To analyze the graph structure, a relatively new and multi-criteria decision making methods of graph theory and matrix approach are used.	Graph Theory and Matrix Approach, DEMATEL	DEMATEL helps the decision makers in identifying the casual relationships among criteria. This relation graph is used in the multi-criteria decision making process. The hybrid methodology is used for the firm selection problem according to their performance in the SC.	
Lin *et al.*/ 2011/ Social and Behavioral Sciences	Automobile / Taiwan	To explore the criteria that influence the performance of the automobile manufacturing industry, using the fuzzy set theory and Decision Making Trial and Evaluation Laboratory.	Fuzzy Set Theory, DEMATEL	Evaluating the performance in automobile manufacturing industry helps firms to comprehend environmental risks and the importance of GSCM in manufacturing process. Cost of purchasing environmentally friendly materials is considered	Future studies need to mention more studies as well as status of automobile industry in various countries to highlight the application GSCM performance in the industry. Future research can also use different methods to identify more criteria to justify the

				most important in the GSCM evaluation.	GSCM performance.
Cuthbertson and Piotrowicz/ 2011/ International Journal of Productivity and Performance Management	Automotive / UK	To propose a common framework for the empirical analysis of supply chain performance measurement systems used in different supply chain contexts.	Case Study	SCPM is a context-dependent process, tailored to specific supply chain requirements. The analysis of the context is necessary, not only to understand the metrics selection and performance achieved, but also to consider opportunities for the application of similar metrics in SCs with similar key characteristics.	Further empirical research is required to fully appreciate the breadth of application of this framework. There is also an opportunity to analyse how selected companies within supply chains measure their performance.
Joshi *et al.*/ 2011/ Expert Systems with Applications	Retail / India	To develop a benchmarking framework for cold chain performance and identifies and prioritizes potential alternatives for continuous improvement.	Delphi-AHP-TOPSIS	With the proposed Delphi-AHP-TOPSIS framework managers easily understand the present strengths and weaknesses of their companies as compared to market leaders. Framework also facilitates the decision makers to better understand the complex relationships of the relevant attributes in the decision-making.	Proposed framework can be used to other sectors with small alterations. Different companies can choose their own factors and sub-factors with different values of relative weights, as per their own goals and business strategies.
Zeydan *et al.*/ 2011/ Expert Systems with Applications	Automotive / Turkey	To introduce new methodology and propose for increasing the supplier selection and evaluate performance for selection of suppliers.	Fuzzy AHP, Fuzzy TOPSIS, DEA	Before the supplier selection and evaluation, both qualitative and quantitative indicators should be considered together and combined. So, risks will be not only minimized and but also be analyzed efficiently and effectively.	Qualitative and quantitative outputs are not the exact decision making tools alone and it can be further analysis.
Kurien and Qureshi/ 2011/ International Journal of Business,	India	To review the literature of performance measurement for supply chains.	Review the Literature, Case Study	SCPM system is critical to effectiveness of SCs and there is requirement to align activities/process with strategy and SC goals.	There is a need for further research in the area of SCPM system.

Management and Social Sciences					
Soni and Kodali/ 2011/ Business Process Management Journal	India	To carry out a critical assessment of empirical research content in supply chain management.		SCM content in empirical research is very much based on analysis of focal firms and most of the authors prefer to perform empirical studies for combination of various entities of analysis considering possible elements of exchange. SCM research is still very much confined in developed countries which is a discouraging.	Future empirical studies must target inter-organizational level more than intra-firm and intra-functional scope at firm level only. Very less empirical studies in SCM are published for developing and underdeveloped countries.
Callender/ 2011/ International Journal of Productivity and Performance Management	Public Sector / Australia	To explore sources of political and administrative challenges.	Case Study	There is an absence of research and debate concerning the alignment of inter-agency supply chains and the potential this creates for delivery performance failure that disadvantages stakeholders.	
Prakash *et al.*/ 2011/ Expert Systems with Applications	India	A complex scheduling problem in flexible manufacturing system address with a novel approach called knowledge based genetic algorithm.	Genetic Algorithm	Paper shows the implication of a new approach for scheduling problem in flexible manufacturing system environment. In this paper, a knowledge based genetic algorithm proposed to improve the performance of the system and improved the effectiveness for FMS scheduling problem with the throughput and mean flow time as the key performance measures.	This research can be stretched out to various problems of the flexible system environment that cover the balancing or allocation of resources. This research can also be employed for the multi-criterion decision-making problems in flexible manufacturing system environment as well as flexible SC environment.
Prakash and Deshmukh/ 2011/ Expert Systems with	India	Multiple vendor transportation problems having a variety of products and multiple customers has been taken	Artificial Immune System, Fuzzy Logic Controller	Owing to the change in hyper mutation rate adaptively at each subsequent iteration, a fuzzy logic controller has been embedded with artificial immune system.	More than two objectives can be taken into account and the same strategy can be extended to the whole supply chain and the same can be incorporated with

Applications		into consideration.			manufacturing systems and their suppliers also.
Aksoy and Ozturk/ 2011/ Expert Systems with Applications	Automotive / Turkey	To aid just-in-time (JIT) manufacturers in selecting the most appropriate suppliers and in evaluating supplier performance.	Neural Network (NN)	Supplier selection and supplier performance evaluation are necessary tools for successful JIT implementation. Results show that NN based supplier selection and supplier performance evaluation systems help manufacturers select the most appropriate suppliers and evaluate supplier performance effectively and simply.	Further research can be carried out by adding new criteria, if required, according to different application areas.
Cai *et al.*/ 2011/ Journal of Purchasing & Supply Management	Manufacturing / China	To investigate the effects of cooperative norms on supplier performance.	SEM	There are complicated, dynamic relationships between cooperative norms, structural mechanisms, and supplier performance in the setting of Chinese manufacturer-supplier relationships.	Future research may need to conduct longitudinal studies to further examine the relationships among the three constructs at different stages of the evolving buyer-supplier relationship. Also, research needs to follow more rigorous procedures to reduce concern of common method variance and to increase the validity of the measures.
Akyuz and Erkan/ 2010/ International Journal of Production Research	Turkey	To provide a critical review on supply chain performance measurement and also reveals the basic research methodologies.	Questionnaire Based Survey	Performance measurement in the new supply era is still an open area of research. Further need of research is identified regarding framework development, empirical cross-industry research and adoption of performance measurement systems for the requirements of the new era.	There is a need of more research and is still an open area of research on supply chain performance measurement. Also there is a need for the development of a framework and empirical testing of the performance measures and metrics for cross-industry also.
Lin and Li/ 2010/ Software Quality Journal	Manufacturing / Taiwan	To propose an integrated framework for supply chain performance measurement.	Case Study	Performance measurement framework provides a solid device for continual improvement in SCM. Framework determines the overall performance of each	

				dimension of a SC and cascade down to the lowest level, which are those entities of a sub-dimension.	
Bigliardi and Bottani/ 2010/ Facilities	Food Industry / Italy	To develop a balanced scorecard models for food supply chain.	Delphi Technique, Case Study	Results show that the companies examined have a similar view for three of the four perspectives of the balanced scorecard, which can be thus considered as validated.	There is a need to validate the balanced scorecard model and the resulting model on a wide sample of companies to test its suitability of adoption for food companies.
EITayeb *et al.*/ 2010/ Journal of Manufacturing Technology Management	Manufacturing / Malaysia	To examine the effect of four drivers, namely regulations, customer pressures, social responsibility, and expected business benefits on green purchasing.		Green purchasing is affected by the drivers namely regulations, customer pressures, expected business benefits, and firm ownership. Also, customer pressures are one of the drivers that have a significant effect on green purchasing.	There is need of study to investigate the effects of other drivers that motivate firms to adopt green purchasing initiatives, such as supplier, competitive, community, and employee pressures. In future it can be repeated using larger samples and different sectors or countries.
Mann *et al.*/ 2010/ The IUP Journal of Operations Management	Canada	To identify the drivers that motivates firms to the move towards creating sustainable supply chain.		This unique view allows for clear delineation of the drivers and will potentially form the basis for future research in sustainable SCM. It provides taxonomy of drivers to situate their role in sustainable SCM.	There is need of more drivers in adoption of sustainable SCM.
Ghijsen *et al.*/ 2010/ Journal of Purchasing & Supply Management	Automotive / Germany	To influence strategies and supplier development, a lack of empirical support exists of their effects on supplier satisfaction and commitment.	Exploratory	Results indicate that supplier commitment is affected by the use of promises and both human- and capital-specific supplier development, while supplier satisfaction is affected by indirect, other direct influence strategies and capital-specific supplier development.	Further research is needed to replicate the study with larger and more representative samples. Additionally, the two constructs regarding relationship-specific supplier development were created specifically for this study and need to be further validated.
Salimifard *et al.*/ 2010/	Banking / Iran	To identify critical success factors of business process re-	ISM	Results identify 9 critical success factors and the relationships between them and highlight the	

International Review of Business Research Papers		engineering projects in banking sector.		level of importance of CSFs.	
Garg and Deshmukh/ 2010/ Asia Pacific Journal of Marketing and Logistics	Automobile / India	To bridge the gap on various issues involved in flexibility on maintenance.	SAP-LAP, Case Study	Various issues concerning flexibility in maintenance are: business or corporate philosophy, systems and processes, inventory, manpower, performance measurements and information systems.	It will be of immense benefit to the future researchers working in this area. Designing PMSs for maintenance organization, which are flexible in nature, may be another interesting area for detailed scrutiny.
Pati and Vrat/ 2010/ Management of Environmental Quality: An International Journal	Paper Industry / India	To analyze the economic impact of blending in sustainable paper industries.	Linear Programmin g	Improving quality of after-use paper by proper recovery network reduces the manufacturing cost. Increasing proportion of wood fiber in the finished paper decreases the cost, even at the cost of degradation in the environment.	There is a need of the further study, the effect of multiple varieties of recyclable after-use paper and reusable paper can be performed and linear model can be extended to include non-linearities, stochasticity of parameters and multiplicity of objectives for future studies.
Awasthi *et al.*/ 2010/ International Journal of Production Economics	Canada	To present a fuzzy multi-criteria approach for evaluating environmental performance of suppliers.	Fuzzy TOPSIS	Fuzzy TOPSIS is used to aggregate the ratings and generate an overall performance score for measuring the environmental performance of each alternative (supplier). The alternative with the highest score is the one with best environmental performance.	This approach can be practically applied in evaluating environmental performance of suppliers.
Faisal/ 2010/ Business Process Management Journal	Manufacturing / Qatar	To present an approach to effectively adapt sustainable practices in a supply chain by understanding the dynamics between various enablers.	ISM	Awareness about sustainable practices is very important as it would lead to undertake efforts to adopt sustainability across SC.	Graph theoretic approach can be applied to develop a quantitative measure of these enablers. Further, AMOS software can be used to test the validity of developed model.
Kumar and	Automobile	To probe the extent and	Regression	Subcontracting relationship with	Automobile industry is

Subrahmanya/ 2010/ Technovation	/ India	diversity of assistance received by SMEs from a Trans-national corporations through subcontracting and its influence on technological innovations and economic performance of SMEs.	Analysis, ANOVA	TNCs is an important source of technological innovations of SMEs in India, contributing to their overall performance.	characterised by outsourcing of large share of parts and components to independent suppliers which needs mutual exchange of information, especially of technical nature. It might be emerged in other industries, such as electronic industry, that offer similar scope for subcontracting between TNCs and local SMEs.
Charan *et al.*/ 2009/ International Journal of Logistics Systems and Management	Automobile / India	To determine the key barriers of supply chain performance measurement system implementation.	ISM	Lack of awareness about performance measurement system in SC is a very significant barrier. A good SCPM system needs to be in place to measure the performance of the SC, thereby making the SC effective and efficient.	SEM approach can be applied in the future research to test the validity of this model.
Keebler and Plank/ 2009/ Benchmarking : An International Journal	USA	To describe the state of logistics performance measurement.	Delphi Technique	Most US firms do not comprehensively measure logistics performance. The focus continues to be on performance within the organization and not on performance between and across firms. Logistics measurement can improve firm performance.	The notion of enablers and barriers is a very important research arena.
Jain and Deshmukh/ 2009/ International Journal of Production Economics	India	To propose a new fuzzy-logic-based hybrid negotiation mechanism.	Fuzzy-Logic	Study takes the advantage of fuzzy logic and develops a hybrid negotiation-based mechanism that combines both cooperative and competitive negotiations. Fuzzy hybrid negotiation mechanism allows negotiation agents more flexibility and robustness in an automated negotiation system.	The proposed fuzzy negotiation mechanism is generic and can be used for wide range of domains, especially in negotiations pertaining to supply contracts for flexible production networks. In future, the concept of game theory can be employed.
Arshinder *et*	Manufacturing	To explore the	Graph-	The decision support tool helps in	This model can be applied to not

al./ 2009/ Computers & Industrial Engineering	/ India	applicability and benefits of the contracts and evaluate of coordination in a two-level supply chain.	Theoretic Approach	coherent decision-making in whole supply chain, mutual sharing of risk and rewards and keeping all the members motivated to form partnership. Different scenarios of coordination may be simulated, which may help in quantifying the performance measures and the effectiveness of coordination.	only newspaper or books industry but can be utilized for other products like pharmaceutical, auto components and perishable products. The two-level supply chains logic can also be extended for multi-level supply chains with more complexity.
Thakkar *et al.*/ 2009/ Benchmarking : An International Journal	Manufacturing / India	To propose an integrated supply chain performance measurement framework for the case of SMEs.	Case Study, Balanced Scorecard and SCOR Model	Poor trust and transparency in buyer-supplier relationship affects the perceived risk related to a supplier's investment. Also, the findings of this research are compared with the other cross-country studies reported on SCM in SMEs.	
Cai *et al.*/ 2009/ Decision Support Systems	Retail / China	To propose a framework using a systematic approach to improving the iterative key performance indicators accomplishment in a supply chain context.	Systematic Approach	Framework quantitatively analyzes the interdependent relationships among a set of KPIs. Identification of coupled relationships among KPIs provides a critical piece of information which helps managers of SC to better grasp the main facets of SCP and take the right actions to enhance the overall performance.	There is a gap between application and research in supply chain performance measurement and improvement.
Sodhi and Son/ 2009/ Transportation Research Part E	Retail Industry / Korea	To model the strategic as well as the operational dimension of performance of supplier–retailer partnerships.	Regression Analysis	The factors that best model strategic performance are different from those that best model operational performance.	There is a need to test the ''spillover'' effect of a few retailers being in many partnerships. Future research could also study the relationships between the five factors themselves using SEM by using a larger sample.
Charan *et al.*/	Automobile	To determine the key	ISM	Awareness about performance	SEM approach can be applied to

2008/ Business Process Management Journal	/ India	supply chain performance measurement system implementation variables.		measurement system in SC is a very significant enabler.	test the validity of such hypothetical models.
Thakkar *et al.*/ 2008/ Asia Pacific Journal of Marketing and Logistics	India	To review the literature on supply chain management practices in SMEs.	Literature Based Research	Paper summarizes the reported literature and classifies it based on their nature of work and contributions. It demonstrates the overall approach towards the development of constructs, research questions, and investigative questions leading to key proposition for the further research.	Outlined propositions and theoretical constructs can be made more precise and focused from continued and cross-sectoral studies.
Slobodow *et al.*/ 2008/ MIT Sloan Management Review	USA	To analyze the buyer-supplier relationship and about the prior literature of measuring supplier and buyer performance.	Two-Way Scorecard	Dual accountability between buyer and its strategic suppliers, through tools such as a Two-Way Scorecard, is a tangible approach to improving SC relationship. There is plenty of discussion of measuring supplier performance but there is no SC metrics for buyers.	There is a need of buyer-supplier relationships and a good communication. Also, there is a need to develop a supply chain metrics for buyers and also require to improve more research on the concepts of dual accountability and the Two-Way Scorecard.
Cousins *et al.*/ 2008/ International Journal of Operations & Production Management	Manufacturing -Service / UK	To develop a model positing in mediating the relationship between supplier performance measures and performance outcomes.	SEM	Study assesses the various relationships between supplier performance measures, socialization mechanisms and firm performance. SEM connecting variables, and found support for a mediating role of socialization mechanisms on the relationship between supplier performance measures and firm performance.	Future research could consider a broader relationship approach examining the interplay of performances measures and socialization across a range of inter-firm relationships, such as alliance partners. Future research could take into account the suppliers' perspective of the effect of performance measurement and socialization mechanisms on their behaviour.
Giannakis/	Service	To develop an analytical		The performance of SRs is	

2007/ Supply Chain Management: An International Journal	Organization / UK	model for assessing the performance of supplier relationships.		assessed in terms of several disparities that exist between the participating parties' perceptions of the nature and their performance to the relationship as well as their perception of their partners' performance to the relationship.	
Jharkharia and Shankar/ 2007/ Omega: The International Journal of Management Science	Manufacturing / India	To present a comprehensive methodology for the selection of a logistic service provider.	ANP	Compatibility between the user and the provider companies is the most important determinant, which influences the final selection process. The ANP approach is capable of taking into consideration both qualitative and quantitative criteria.	The model may also be subjected to a sensitivity analysis. Further evaluation and refinement of the model using additional field studies may prove beneficial in developing an intelligent system, which would advise the decision-makers about the low significance of certain enablers and dimensions.
Qureshi *et al.*/ 2007/ International Journal of Productivity and Performance Management	India	To model the key variables of logistics outsourcing relationship between shippers and logistics service providers.	ISM	Finding of this modeling helps shippers as well as LSPs to take various initiatives, in order to have prosperous, outsourcing relationship between shippers and LSPs. Top management from both shippers as well as LSPs should focus, on improving on the enablers such as trust or commitment, and top management support.	SEM may be applied to test the validity of such hypothetical model. Statistical software like Amos. can be used in future to build correlation matrix and confirmatory factor analysis to validate the relationship.
Choy *et al.*/ 2007/ Benchmarking : An International Journal	Airlines / Hong Kong	To develop a performance measurement system in the application of supplier relationship management operated under a supply chain benchmarking framework.	Case Study	PMS helps a company and its suppliers to understand the performance gap between its service levels with the best-in-class practice. The resulting performance gap provides valuable information in the formulating of a new supply chain and strategic plan in solving	

				problems and challenges in aviation industry.	
Gaiardelli *et al.*/ 2007/ Computers in Industry	Automotive / Italy	To propose an integrated framework for the after-sales network performance measurement.	Case Study	Performance measurement systems of different supply chain actors should be aligned in order to achieve strategic consistency. The performance of different actors at the process level of the framework concurs in determining the after-sales service overall performance towards the final customer.	The empirical application was limited to a specific industry and to the interface between two specific players. Further evaluation of the framework is thus needed, involving more industries and more supply chain levels.
Hult *et al.*/ 2007/ Industrial Marketing Management	Transportation Company / USA	To examine the influence of transactional and transformational leadership on the relationship between the value of the corporate buying center and performance in supply chains.	CFA, SEM	Transformational leadership has a positive influence on the relationship between the corporate buying center's value and performance of the SCO, while transactional leadership had a negative effect on this relationship.	
Bhagwat and Sharma/ 2007/ Computers & Industrial Engineering	Manufacturing / India	To develop a balanced scorecard for SCM.	Case Studies, Balanced Scorecard	Performance measurement is an essential element of effective planning and control as well as decision making. The measurement results reveal the effects on strategies and potential opportunities in SCM.	Future research is recommended in order to determine whether the proposed perspectives and measures are a necessary and sufficient set.
Wong and Wong/ 2007/ Industrial Management & Data Systems	Singapore	To use data envelopment analysis (DEA) in measuring internal supply chain performance.	DEA	Information from the DEA models helps manager to identify the inefficient operations and take the right remedial actions for continuous improvement. Also results indicate that not all technically efficient companies are allocative efficient.	There is a lack of tools to measure SC efficiency. There is possibility of modeling DEA in a stochastic SC environment since SC operates in a dynamic environment.
Zhu *et al.*/	Automotive	To explore the GSCM	Regression	China will become one of the	There is a need for a longitudinal

2007/ Journal of Cleaner Production	/ China	pressures/drivers, initiatives and performance of the automotive supply chain.	Analysis, Case Study	largest producers and users of automobiles and their parts. Chinese automobile SCs have struggled to improve their economic and environmental performance simultaneously.	and broad-based investigation to arrive at a more lucid picture of environmental sustainability practices in the Chinese automotive supply chain.
Modi and Mabert/ 2007/ Journal of Operations Management	Manufacturing / USA	To present a conceptual model of an organization's efforts to improve supplier performance.	Latent Variable Structural Equation Modeling	Evaluation and certification efforts are the most important supplier development prerequisites before undertaking operational knowledge transfer activities.	
Kim/ 2007/ International Journal of Production Economics	Manufacturing / Korea	To suggest a set of best organization structures for efficient SCM and identify organizational characteristics, which have significant influences on SCM performance.	ANOVA	More dynamic and extensive approach in reaching the best organization type for SCM performance is necessary.	There is a need of firm-level performance measures such as financial and market performances. Same study can be done with a sample of USA and European firms.
Saad and Patel/ 2006/ Benchmarking: An International Journal	Automotive / India	To investigate the relevance of the concept of supply chain performance and identify performance measures sets for SCP.	Qualitative and Quantitative Methods, Factor Analysis	Concept of SCP is not fully embraced by the Indian automobile sector and highlights the difficulties associated with its implementation. Also suggests that there is awareness about the need to measure and continuously improve performance.	The Indian automotive sector is not embracing the whole philosophy of supply chain performance. This can be interpreted as either a lack of proper understanding of the concept or an interesting attempt to adapt the concept to the Indian context and culture.
Agarwal *et al.*/ 2006/ European Journal of Operational Research	India	To explore the relationship among lead-time, cost quality, and service level and the leanness and agility of a case supply chain in fast moving consumer goods business.	ANP	Leanness in a supply chain maximizes profits through cost reduction while agility maximizes profit through providing exactly what the customer requires. The ANP methodology is a robust multi-attribute decision-making technique for synthesizing the criteria, enablers and dimensions	

				governing the SC performance.	
Dangayach and Deshmukh/ 2006/ Omega: The International Journal of Management Science	Manufacturing / India	To present findings of a survey on manufacturing strategy practices adopted by the Indian machinery manufacturing companies.	Case Study	In machinery manufacturing industry lead-time plays an important role. Due to easy import policy of government of India, better quality machine tools are available at competitive prices in a shorter time from the foreign competitors.	More research with larger sample is required to generalize the findings and this study can also be done for other industry.
Pati *et al.*/ 2006/ International Journal of Production Economics	Pulp & Paper / India	To present a linear optimization model for paper industry and to minimize the cost of paper in the supply chain.	Linear Programmin g Technique	Study helps in selecting the most economical raw material for manufacturing paper. Results also encourage the manufacturer / managers and SC partners to consider wastepaper as raw material for an alternative and economic option of manufacturing paper compared to virgin wood pulp as raw material.	
Sarkar and Mohapatra/ 2006/ Journal of Purchasing & Supply Management	India	To developed a systematic framework for carrying out the supply base reduction process.	Fuzzy Approach	Performance of a supplier represents short-term effects on the achievement of SC objectives while supplier capability indicates long-term effects.	There is a need for further development that how to develop a mechanism for continuously evaluating supplier performance and maintenance of knowledge base of suppliers and also how to develop and build a sustainable relationship with this reduced supply base.
Shepherd and Gunter/ 2006/ International Journal of Productivity and Performance	UK	To address the dearth of research into performance measurement systems and metrics of supply chain.	Systematic Review Methodology	The paper argues that despite considerable advances in the literature in recent years, a number of important problems have not yet received adequate attention, including: the factors influencing the successful implementation of performance	There is need to consider developing measures of SC relationships and the SC as a whole, rather than measures of intra-organizational performance. Future research needs to explore how to design performance measurement systems which

Management				measurement systems for SCs; the forces shaping their evolution over time; and the of their ongoing maintenance. Few studies have developed performance measurement systems, delineated metrics, or benchmarked supply chain practices. There has been limited reflection on important insights from the wider contemporary literature on performance measurement.	complement human resource management and modern manufacturing practices. Further there is need to investigate the factors influencing the evolution of performance measurement systems for SCs and how to handle their ongoing maintenance.
Chan *et al.*/ 2006/ Benchmarking : An International Journal	Postal Industry / Hong Kong	To develop a new benchmarking process for continuous improvement against the market leader.	AHP	The proposed framework evaluates the performance of the company against its competitors. It also helps the company to select the best improvement alternative for implementation in order to enhance its performance on the weakest measures.	AHP approach can be applied in other industries as different industries may have their own goals and operational strategies also the benchmarking outcome can provide a best solution meeting their existing and future business strategies. Proposed framework can also be applied to other industries with a little modification.
Tan and Kumar/ 2006/ The International Journal of Logistics Management	Electronics / Singapore	To present a decision-making model for manufacturers to maximize their profits in reverse logistics operations.	System Dynamic Model	The results indicate that part replacements from suppliers are more profitable than refurbished computer parts. Transportation delay and supplier delay in processing returns have a significant impact on the viability of reverse logistics regardless of return volumes.	Product depreciation should be considered for future model especially with industry where product life cycle is short. This model can be applied to other industries to determine its applicability like in the chemical and automotives industries.
Burgess *et al.*/ 2006/ International Journal of Operations & Production	Manufacturing / Australia	To clarify some aspects of the emerging perspective in the field of supply chain management.		The SCM is a relatively "young" field with exponential growth in interest from researchers.	

Management					
Ravi *et al.*/ 2005/ Computers & Industrial Engineering	Computer Hardware / India	To structure the problem related to options in reverse logistics by using ANP approach.	Balanced Scorecard and ANP	The reverse logistics practices may cost in millions of dollars for company. The implementation of these may be a risky endeavor for the top management as it involves financial and operational aspects, which can determine the performance of the company in the long run.	A possible extension of this research study might be to study the preferences of the user companies corresponding to different sizes and sectors, where these criteria may be modeled as per the choice of companies. The model may also be subjected to sensitivity analysis.
Laamanen/ 2005/ Research Policy	Telecommunications, Automotive / Finland	To examine the effects of supplier dependency and resource depth on the performance of telecommunications suppliers during an industry downturn.	Regression Analysis	R&D carried out by a supplier independently relates strongly positively to the technological depth of a supplier's offering, which is in turn positively related to supplier performance. A supplier should try to develop the depth of its technological competencies, both alone and together with its main client.	For future research one would be to extend the model of supplier performance during a downturn with additional variables. Another potential extension would be the development of dynamic measures for R&D collaboration.
Ravi and Shankar/ 2005/ Technological Forecasting & Social Change	Automobile / India	To analyze the interaction among the major barriers.	ISM	Lack of the awareness of reverse logistics practices is a very significant barrier. Therefore, top management should focus on developing strategies to create awareness about the use of reverse logistics so that the benefits of it can be reaped.	SEM technique can be applied to test the validity of this model in future.
Fynes *et al.*/ 2005/ International Journal of Production Economics	Electronic / Ireland	To develop a conceptual framework incorporating dimensions of SC relationships and quality performance.	SEM	Supply chain relationship quality has a positive impact on design quality but not on conformance quality. This suggests that by developing and engaging in true partnership types of SC relationships, suppliers can become much more proactive in the design and new product	Future research could examine issues such as customer perceptions of the nature of SC relationships, supplier quality, and quality performance. Finally, cross-national comparisons of SC relationships and quality management could also provide a fruitful field of research endeavour.

				development process.	
Samaranayake / 2005/ Supply Chain Management: An International Journal	Manufacturing / Australia	To document the research on development of a conceptual framework for the SC and to provide a methodology for planning of many components in the SC.	Unitary Structuring Approach	The numerical testing shows that each network in the SC provides an integrated approach to planning and execution of many components, and is capable of providing visibility, flexibility and maintainability for further improvement in the SC environment.	Framework could be developed as a generic SC model and a software module and/or implemented in existing enterprise resource planning and other systems where these systems support object oriented database structure.
Sachan and Datta/ 2005/ International Journal of Physical Distribution & Logistics Management	India	To examine the state of logistics and supply chain management research in the last five years from the standpoint of existing methodologies.	Multi-Method Approach, Qualitative Method, Simulation, Case Study	There is an increase in the direct observation methods like case studies. The research is more interpretive in nature. Survey method is still holding the highest position.	More research as on today is focusing at the function or at the firm level. More research is needed at inter organisation level then only one can develop an appreciation of concept SC.
Folan and Browne/ 2005/ Computers in Industry	Ireland	To describe the evolution of performance measurement and examine the performance measurement literature into the processes related to performance management.	Case Study	The PM literature shows clear tendencies to merge with the separate body of performance management research, as-throughout its evolution-it has continually encroached upon areas that that research influences.	
Gunasekaran *et al.*/ 2004/ International Journal Production Economics	UK	To develop a framework to promote a better understanding of the importance of SCM performance measurement and metrics.	Empirical Analysis	Performance measurement and metrics have an important role to play in setting objectives, evaluating performance, and determining future courses of actions. To bring about improved performance in a supply chain and move closer to attainment of the illusive goal of supply chain optimization, performance	Industry consortiums, consultants, and researchers could be helpful in promoting SCM performance measurement generally, and in developing measures and measurement techniques specifically.

				measurement and improvement studies must be done throughout the supply chain.	
Prahinski and Benton/ 2004/ Journal of Operations Management	Automotive / USA	To determine how suppliers perceive the buying firm's supplier evaluation communication process and its impact on suppliers' performance.	SEM	When the buying firm uses collaborative communication for the supplier development programs, it is perceived by the supplier as an effective mechanism to improve the buyer-supplier relationship.	Further theoretical work could expand the model by including other dimensions of communication strategy.
Schmitz and Platts/ 2004/ International Journal of Production Economics	Automotive / UK	To offer a brief discussion of the literature on inter-organisational performance measurement and contrast existing concepts of intra-organisational performance measurement with the concepts of performance measurement within a SC.	Case Study	Supplier performance measurement appears to be an important tool in the automotive industry. Mainstream literature emphasises the use of ''integrative'' measures and the measurement of ''overall supply chain performance''.	Future studies should therefore aim to, first, take into consideration the suppliers' perspective on the evaluation process, and second, include a broader view of supplier evaluation.
Melnyk *et al.*/ 2004/ Journal of Operations Management	USA	To convey the importance and need for metrics-related research.	Case Study	There was suggested an outline of what we see as important characteristics by which the research space can be organized, and provided some initial theoretical grounding for this research in agency theory, dependency theory, strategic fit theory, information processing theory, and linkage research.	
Humphreys *et al.*/ 2004/ Omega: The International Journal of	Electronic / Hong Kong	To examine the role of supplier development in the context of buyer-supplier performance from a buying firm's perspective.	Factor Analysis, Regression Analysis	This study provides an improved understanding of the impact of supplier development on buyer–supplier performance.	Further research is needed to corroborate these findings with larger and more representative samples and to investigate supplier development activities in other industrial sectors.

Management Science					
Dangayach and Deshmukh/ 2003/ International Journal of Production Economics	Manufacturing / India	To present findings of an extensive survey of Indian manufacturing companies.		Economic reforms and global competition have given Indian manufacturing companies an opportunity to look at the strategic role of manufacturing and motivated Indian companies to give high priority to quality management. Indian companies are giving less importance to flexibility.	In future, other industries could be considered like service sector and software sector. Further, the correlation between manufacturing competence and business performance measures may provide further insight into the practices followed by Indian companies.
Schmitz and Platts/ 2003/ Management Decision	Automotive / UK	To develop a conceptual framework describing the roles of supplier performance measurement.	Qualitative and Case Study	Supplier performance measurement appears to be an important tool in the automotive industry. Study suggests that the use of performance measurement in the inter-organizational context emphasizes different roles than the use of intra-organizational performance measurement.	Future studies should aim to, first, take into considerations the suppliers' perspective on the evaluation process, and second, include a broader view of supplier evaluation. And future studies addressed, how does performance measurement affect the buyer-supplier relationship?
Chung and Kim/ 2003/ Research Policy	Automobile and Electronic / Korea	To analyze the effects of supplier involvement in a manufacturer's new product development on the supplier's financial performance, innovation, and product quality.	ANOVA	The results indicate that a higher level of supplier's involvement positively influences innovation and financial performance.	It may be made finer distinctions on the level of supplier involvement based on components development cycles and levels of technology for diverse components in the future research.
Kleijnen and Smits/ 2003/ Journal of the Operational Research Society	Manufacturing / Netherlands	To propose to deal with multiple metrics in SCM via the balanced scorecard; which measures customers, internal processes, innovations, and finance.	Balanced Scorecard	SC consists of so many links that we can distinguish upstream, midstream, and downstream companies. Other types of SCs may be studied like buyer's market for the SC's final product versus seller's market. Sensitivity analysis helps validate the simulation model, provides	Such a research agenda may result in both an integrated methodology for performance evaluation (cost/benefit analysis) of SCs, and general results on the main drivers of these costs and benefits.

				insight into the behaviour of the SC, and gives the critical control factors.	
Chan/ 2003/ International Journal of Advanced Manufacturing Technology	Electronic / Hong Kong	To present the formulization of both quantitative and qualitative performance measurements for easy representation and understanding.	AHP	Different SCs are different for various industries. Customers should be the main concern of a company whereas cost is not really related to the customers. Finally, this method is important to help the managers to choose from their alternative SCs.	
Chan and Qi/ 2003/ Integrated Manufacturing Systems	Hong Kong	To propose a process-based approach to mapping and analyzing the practically complex supply chain network and to identify the performance and metrics.	Performance of Activity Approach	The complexity of practical supply chain shapes the difficulties in mapping supply chain structure, managing integrative relationship, and measuring the system performances. Besides structure analysis, this approach is used to build the process-based performance measurement of SCM.	There is a need of a suitable approach to aggregating the existing or new performance measures into the holistic, integrated system in order to assess the SC. This study also identifies the gap for future research in performance measurement of SCM.
Bullinger *et al.*/ 2002/ International Journal of Production Research	Germany	To describe a supply chain analysis approach and proposes a measurement methodology.	Balanced Measurement Methodology	There is no unique way to define the roadmap towards an optimal supply chain measurement. Results provide logistical networks with an innovative instrument to design a supply-chain-wide balanced performance measurement.	
Husain *et al.*/ 2002/ Journal of Engineering and Technology Management	Automobile / India	To analyze technology management practices of firms in the automobile industry in India.	Case Study, Situation Actor Process Learning Action Performance	Collaborations are very effective when the local firm has the competence to absorb the acquired technology within the period already decided by both the parties. Active long term collaborations are essential for	

			(SAP-LAP)	building technological strengths in the firms of developing countries.	
Frohlich/ 2002/ Decision Sciences	Manufacturing / UK	To address the questions using data from a large single nation study.	SEM	Results suggest that managers interesting in improving their company's SC using e-integration should first focus on internal barriers. Achieving strong upstream and downstream e-integration is the correct goal for companies to work towards.	Provided reliable and valid scales for measuring upstream supplier and downstream customer e-integration can facilitate future work in this area and should prove valuable to other SC researchers.
Lai *et al.*/ 2002/ Transportation Research Part E	Transport Logistics / Hong Kong	To investigate the construct of, and develop a measurement instrument for, supply chain performance (SCP) in transport logistics.	CFA	The measurement instrument is reliable and valid for evaluating SCP in transport logistics.	Future research can also focus more on the relationship between SCP in transport logistics and other constructs, such as competitive advantage. There is a need to extend the study of SCP to other logistics contexts in the SC.
Lambert and Pohlen/ 2001/ The International Journal of Logistics Management	USA	To provide a framework for developing supply chain metrics that translates performance into shareholder value.		By maximizing profitability at each link, supply chain performance migrates toward management's objectives and maximizes performance for the whole.	Future research is required to test the proposed framework in an actual business setting. Barriers to implementation and how they can be overcome need to be identified.
De Toni and Tonchia/ 2001/ International Journal of Operations & Production Management	Manufacturing / Italy	To increase the importance of performance measurement in operations management.	Principal Component Analysis	The primary result obtained about the nature of the structure of the PMS itself. Generally a PMS integrates with: the accounting system; manufacturing planning and control system; the strategic planning system.	There is need a relationship between the PMS variables and external variables and the extension of the investigation to small and medium-sized enterprises and the service firms.
Gunasekaran *et al.*/ 2001/	USA	To develop a framework for measuring the strategic, tactical and	Literature Survey	There were no performance measures for the complete supply chain. Many companies have this	A lack of balanced approach between financial and non-financial performance measures

International Journal of Operations & Production Management		operational level performance in a supply chain.		problem. Those that do not have such metrics often do not monitor them regularly. Or their metrics are not directly related to customer satisfaction.	and the study can be done on the performance measures for the complete SC. To bridging the gap between the need for a model with which performance of a SC can be assessed, and the potential areas of improvement that can be identified.
Beamon and Chen/ 2001/ International Journal of Production Research	USA	To concern the performance behavior of conjoined supply chains.	Experimental Design, Simulation Analysis	Results indicate that inventory system stock-out risk, the probability distribution of the demand, and the transportation time was most important in determining the effectiveness of the chain.	There are numerous factors important to SCP therefore the general approach can be used to illustrate, in practice, what factors should be examined first and developed model allow for further analysis of many different supply chain configurations and operational characteristics.
Tan/ 2001/ European Journal of Purchasing & Supply Management	Manufacturing / USA	To review the literature base and development of supply chain management.		Poor supplier performance is not the only risk; the purchaser needs to worry about the possibility of a supplier passing trade secrets to competitors or with its new-found abilities, venturing out on its own.	To further exploit the competitive advantage associated with integrated processes, some leading organizations adopt a strategic approach to managing the value chain, such as forming strategic alliances with suppliers and distributors instead of vertical integrating; inter-company competition is elevated to inter-supply chain competition.
Van Hoek/ 2001/ International Journal of Operations & Production Management	Logistics Service, Transport / USA	To bring together operations and management control special issues on performance measurement.	Case Study	The expansion of horizontal third party alliances, through the offering of supplementary services (customization etc.), is not a “common practice” in this sector. Leveraging the SC thus requires innovation in measurement and control.	
Dangayach and	Manufacturing /	To observe the manufacturing strategy	Case Study	To achieve the competitive priorities, the role of	An action plan is required to translate the manufacturing

Deshmukh/ 2000/ Journal of Manufacturing Systems	India	practices in select Indian organizations.		infrastructural issues is very important. Top management must give its attention to improve on these issues rather than just keeping the equipment running.	mission into reality; such a plan is expected to be market and product specific.
Stank and Goldsby/ 2000/ Supply Chain Management: An International Journal	Transport, Logistics / USA	To clarify the major transportation decision areas and introduce a framework that positions corporate transportation management within the overall integrated SC environment.		Managers must encourage their firms to view the total cost and total value provided by carriers, and refrain from buying transportation solely based upon lowest transactional cost.	Further research areas include what information to exchange and how often, what performance measures to monitor, how to collect them and how often.
Brewer and Speh/ 2000/ Journal of Business Logistics	USA	To discuss the concept of SCM and the limitations of traditional logistics performance measures and provides an overview of balanced scorecard performance measurement systems.	Balanced Scorecard	Use of this novel approach help employees and managers focus attention on achieving goals that are beyond the typical measures of performance used within firms.	Future challenge for managers are to craft additional metrics that focus on key supply chain process and interactions.
Shin *et al.*/ 2000/ Journal of Operations Management	Automotive / USA	To test the impact of a supply management orientation on the suppliers' operational performance and buyers' competitive priorities (cost, quality, delivery, flexibility).	Principal Component Analysis, SEM	An improvement in supply management orientation improves both the suppliers' and buyers' performance especially when the buyer emphasizes quality and delivery as its competitive priorities. Further, supply management' is not a panacea to improve all the competitive priorities of the buyer.	Future research can improve this research by using more than two supply chain participants (supplier and buyer); and using more than two performance indicators for the 'Buyer Cost Performance' and Buyer Flexibility Performance' constructs, respectively.
Croom *et al.*/ 2000/ European Journal of Purchasing & Supply	UK	To set out not to review the supply chain literature per se, but rather to contribute to a critical theory debate through the presentation and use of a	Content and Methodology -Oriented Criterion	The inductive-deductive dichotomy is best addressed through the constant reflection of empirical against theoretical studies.	Future developments in theory concerned with business to business phenomena may require a more cosmopolitan approach, incorporating a combination of contrasting social and technical

Management		framework for the categorisation of literature linked to SCM.			disciplines.
Beamon/ 1999/ International Journal of Operations & Production Management	Manufacturing / USA	To present a framework for the selection of performance measurement systems for manufacturing supply chains.	Quantitative Approach	Performance measurement selection is a critical step in the design and evaluation of any system. The categorization of SCP measures resulted in the identification of three types of performance measures that are necessary components in any SCP measurement system: resource, output and flexibility.	There is an ever-increasing number of supply chain models presented in literature, there is very little available in SCP measure selection.

2.12 Conclusion

In this chapter, different key factors of supply chain performance measurement and barriers in the Indian automotive supply chain have been discussed. In the initial part of this chapter, a brief introduction of the Indian automotive industry and supply chain performance measurement has been given. A literature review presented different definitions of supply chain and supply chain performance measurement. The literature has been categorized into several important categories like; journal, period of publication, industry, country, research issues and gaps, and methodology adopted for analysis. From a literature review, a conceptual model was developed and presented in this chapter. This chapter shows the various gaps in the literature, which resulted in the objectives of this research. To achieve these objectives, this present chapter provides a strong foundation for the use of different new methodologies that has been applied in the following chapters of the thesis.

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CHAPTER 3

Modeling the Key Factors of Supply Chain Performance Measurement

Preview

The purpose of this chapter is to investigate the interactions among the key factors of supply chain performance measurement in the Indian automotive industry. These key factors are helpful to measure supply chain performance and to improve the firm's effectiveness. For this objective, an interpretive structural modeling (ISM) with a fuzzy cross-impact matrix multiplication applied to classification (fuzzy MICMAC) based approach is used to examine the interactions among the key factors of supply chain performance measurement. The most dominant key factors were identified and used for measuring the performance in automotive supply chain. Such relationships among the key factors can help a firm's top management to make essential judgments in order to solve the overall supply chain problems and provide a better approach to proactively deal with problems.

3.1 Introduction

Supply chain performance measurement (SCPM) has been receiving incessant attention from the practitioners as well as from researchers since last two decades. In current business environment, supply chain management (SCM) plays a vital role in business activities, manufacturing industries and the service industries for increasing their effectiveness, efficiency, customer service, and profit. Gunasekaran *et al.* (2001) mentioned that SCM is an important and specialized management tool for increasing a firm's efficiency and reaching their goals. Therefore, it is mandatory for industries to focus on the key performance measures of supply chain (SC). According to Ren *et al.* (2004), planning and operations have significant influence on supply chain performance (SCP). The authors also stated, "you cannot manage what you cannot measure". SC logistic performance was perhaps an initial attempt to define supply chain performance (Chia *et al.*, 2009). A unique attribute of a SCPM is that the measurement system covers the entire SC including the measurement of interdependencies cross the borders of firms (Beamon, 1999; Gunasekaran *et al.*, 2001; 2004; Shepherd and Gunter, 2006). Performance measurement is an essential tool for companies to improve efficiency and effectiveness of SC (Beamon, 1999; Neely *et al.*, 2002; Shepherd and Gunter, 2006).

In recent years, several theories of managing the performance of the SC are discussed in literature (Brewer and Speh, 2000; Park *et al.*, 2005; Yeh; *et al.*, 2007). Gunasekaran *et al.* (2001; 2004) proposed a framework related generic processes for measuring the operational, tactical and strategic levels of performance in a SC. Choy *et al.* (2007) developed a system of performance management for measuring associated suppliers using a benchmarking structure. Charan *et al.* (2008) shown that a better SCMP system promotes a strong relationship between the SC members. In today's business surroundings, a long-term relationship among the different parties of a SC is essential. Although most of the industries have realized the importance of an extended SC and new technologies, nevertheless, many of them still do not have effective strategies for a completely integrated SC. Saad and Patel (2006) analyzed the structure of SCP measure and the difficulty of implementing such measures in the Indian automotive industry. The authors found that the Indian automotive industries are not implementing the important concepts of SCM properly. In past few years, several attempts are made from the Indian perspectives to measure SCP at industry level. However, only a few of them have actually implemented. Since recently, the Indian market has opened for foreign companies to invest and work, the Indian automotive sector is flooded with automotive manufacturers like Honda, Toyota, and Ford etc. This has generated a tough competition among automotive companies in terms of product cost, quality, delivery, and flexibility. To compete companies are trying to improve the overall performance of their SC. The primary focus of this chapter is to investigate the different key factors of SCPM in the Indian automotive industries. The reason behind focusing on automotive industry is that it has been fastest growing sector in India and has more than 10% contribution in Indian GDP (Joshi *et al.*, 2013). It is mandatory for all industries to focus on better strategy, technology and other customer requirements to develop an effective measurement system for SCP. This will result in a deeper understanding of the SC and improve its overall performance (Sharma and Bhagwat 2007; Chen and Paulraj, 2004). Gunasekaran and Kobu (2007) mentioned that it is essential, but at the same time a major challenge, for the firm's top leaders to develop appropriate key factors to measure SCP. However, there is a lack of awareness about identification of the factors that affect business performance. Very few studies are present in literature on identification of key factors for measuring SCP from the Indian context (Charan *et al.*, 2008; Ganga and Carpinetti, 2011).

The primary objective of this chapter is first to identify different key factors of SCPM from a literature review and discussion with experts of Indian automotive industry. The secondary objective is to investigate the interrelationships among the identified key factors of SCPM. The ISM approach (Warfield, 1974; Sage, 1977) was utilized to investigate the interrelationships among different key factors. Further, in order to categorize the key factors according to their dependence and driving power, we integrated the ISM approach with a fuzzy cross-impact matrix multiplication applied to classification (fuzzy MICMAC) (Duperrin and Godet, 1973; Saxena *et al.*, 1992). Fuzzy MICMAC is derived from the fuzzy direct relationship matrix; the significance of a criterion is considered less by its direct interrelationships and more by its various indirect interrelationships (Qureshi *et al.,* 2008). Fuzzy logic is an appropriate method to deal with vagueness and subjectivity, which becomes an exciting supporting approach to manage SCP (Ganga and Carpinetti, 2011). Therefore, we used integrated ISM and fuzzy MICMAC together to categorize the key factors according to their dependence and driving powers.

The remainder of this chapter is organized as follow. Section 3.2 discusses identified different key factors of SCPM. Section 3.3 describes the research methodology. The ISM approach for modeling the key factors is discussed in section 3.4. Section 3.5 illustrates the integration of ISM and fuzzy MICMAC approach to understand the driving power and dependence power of the key factors. Section 3.6 discusses the conclusion and managerial implications of this chapter.

3.2 Identifying the key factors of supply chain performance measurement

In this objective, the different factors of SCPM are identified from the literature review. After identification of key factors for SCPM, a brainstorming session was held with sixteen experts at the managerial level who have minimum ten years' experience in the area of automotive SCM. The factors identified from the literature were distributed among the experts panel to discover the relevance of these factors in the automotive SCM. Based on the experts' opinion, twenty key factors were finalized that affect SCP. Finally, the experts were asked to establish the interrelationships among the finalized key factors. The list of the twenty key factors related to SCPM has been shown in Table 2.4 (see Chapter 2). These key factors are discussed below in more details.

3.2.1 Order entry method

The order entry method helps to determine the requirement of the consumers, which converted into information and exchanged across the different parties of SC (Gunasekaran *et al.,* 2001; 2004). SC may face huge loss, if the customers' requirements are not exchanged correctly at different stages of SC. It is important factor of the order planning measures and it can be improved through various efforts and associations among the different partners of SC (Gunasekaran *et al.,* 2004; Bhagwat and Sharma, 2007). Cho *et al.* (2012) mentioned that order entry method is one of the important key factors of SCPM.

3.2.2 Order lead-time

The total order cycle time refers to the time between receiving a consumer's order and product delivery and it is also referred as order lead time (Gunasekaran *et al.,* 2004). Order lead-time is another significant key factors and a base of economic advantage (Bower and Hout, 1988; Christopher, 1992; Gunasekaran *et al.*, 2001) as it directly affects the level of buyer satisfaction (Towill, 1997). A decrease in the order lead-time helps to reduce the response time of a firm's SC (Christopher, 1992; Gunasekaran *et al.,* 2004; Bhagwat and Sharma, 2007).

3.2.3 Customer order path

The customer order path determines the amount of time spent on different parts of the SC or a series of activities that need to deliver a service (Cho *et al.*, 2012). Inefficiencies can be identified and corrected by analysis of customer order path (Gunasekaran *et al.,* 2004). According to Bhagwat and Sharma (2007), the whole process of the customer order path includes various activities such as the customer ordering status, order lead-time, delays in documentation, time spent in the storehouse, time used in product inspection and rechecking (Gunasekaran *et al.*, 2001). Therefore, it is one of the key factors of SCPM. These different problems can be removed by deploying the JIT, IT, and advanced engineering methods.

3.2.4 Supplier selection

Supplier selection plays a noteworthy role for both parties (buyer and supplier) in terms of cost and time reduction, which can improve the value and quality of the commodities (Aksoy and Ozturk, 2011). Selecting a good supplier can minimize the manufacturing costs and lead-time (Meena *et al.,* 2011; Meena and Sarmah, 2013). Braglia and Petroni (2000) revealed that firms benefit from a better supplier selection and a high level of reliability, since it reduces inventory costs and improves product quality. Thus, efficient supplier selection is an important key factor of SCP and potential research area.

3.2.5 Purchase order cycle time

Purchase order cycle time treated with greater significance for fast and efficient delivery. It begins when materials are needed by a supplier, and is followed by many steps. Each step of the process is significant. Boer *et al.* (2001) suggested that the implications of the purchasing function and purchasing judgments have become more significant. As firms become more dependent on suppliers, the direct and indirect costs of poor decision-making become more severe (Aksoy and Ozturk, 2011). The purchase order lead-time can have a significant impact on a company's base line. It is a key element of the delivery cycle time, along with the time it takes to make and deliver the product.

3.2.6 Buyer-supplier relationship

A strong relationship between buyer and supplier emphasizes the long-lasting relationship and future planning for any business. Many studies (Ellram, 1991; De Toni *et al.,* 1994; Towill, 1997; Mahdavi *et al.*, 2010; Meena and Sarmah, 2012) have emphasized the importance of strong relationship/partnerships for good SC operations. Selection of appropriate suppliers and an effective supplier relationship management are the key factors for increasing the competitiveness of firms (Ghodsypour and O'Brien, 2001; Aksoy and Ozturk, 2011; Choy *et al.,* 2003a).

3.2.7 Mutual assistance in solving problems

A strong partnership emphasizes a long-term relationship, mutual planning and problem solving efforts (Maloni and Benton, 1997). If a buyer-supplier relationship is strong, then their mutual understanding can be very helpful to solve different problems. Presently, trader partnerships has been given a lot of attention from businesses and researchers, resulting in a stable stream of supporting literature (e.g. Ellram, 1991; MacBeth and Ferguson, 1994; Landeros *et al.,* 1995; New, 1996; Maloni and Benton, 1997; Bhagwat and Sharma, 2007). Meena and Sarmah (2012) mentioned that to have a long-term relationship, both parties must be satisfied with each other's performance. Furthermore, mutual assistance supports the development of the buyer-supplier partnership.

3.2.8 Effectiveness of a master production schedule

Master scheduling in SC planning is used for scheduling the production throughout the SC, validating and managing the production plan. Scheduling deals with the distribution of resources and tasks over time to perform a set of activities (Cho *et al.,* 2012). Gunasekaran *et al.* (2001) stressed that suitable measures need to be taken to improve the master production schedule in SCM, since it provides the foundation for order promising and links the total production plan to the manufacturing of specific items, quantities, and dates. Scheduling also has a major impact supplier performance, capacity utilization, and customer satisfaction (Cho *et al.*, 2012). According to Robinson *et al.* (2008), scheduling depends on customer needs and supplier performance in the SC.

3.2.9 Capacity utilization

Capacity utilization is another aspect of performance measurement and plays an important role in determining the performance level in a supply chain. Capacity utilization is a factor that indicates how well capacities are used in the delivery of services (Fitzgerald *et al.*, 1991). Wild (1995) stated that each manufacturing schedule takes a position inside the structure set by capacity assessments. It clears the significance of determining and managing the capacity utilization (Bhagwat and Sharma, 2007).

3.2.10 Product cost

Product cost comes under the output measures of production performance and it includes the quality and quantity of the final product and customer responsiveness. Manufacturers and researchers have argued that dealing with a limited number of suppliers leads to better quality and a lowering of the product cost (Kekre *et al.*, 1995; Meena *et al.*, 2011; Meena and Sarmah, 2013). According to John *et al.* (2006), product costs are very important for decision making within the production process. The final resources affect the production of a SC, and the output of the SC system is important in determining the flexibility of the system. In this case, the output performance measures should be utilized properly (Beamon, 1999; Neely *et al.*, 2002).

3.2.11 Quality

Quality is the most important factors of the production performance that is used to maintain product quality. Attributes like cost, quality, delivery, innovation and flexibility are considered a competitive priority factor or end goal of a firms' performance in terms of customer expectations

(Hill, 1987; De Toni and Tonchia, 1998; Sharma *et al.*, 2013). Dangayach and Deshmukh (2001) also highlighted that high quality and the performance values of any manufactured product are crucial. Indian companies are based on their quality that is reported in a survey of manufacturing companies (Chandra and Sastry, 1998).

3.2.12 Flexibility

Flexibility is an important measure of production performance. According to Robinson *et al.* (2008), flexibility is particularly important when controlling the master production schedule, in which an effort to maintain "schedule flexibility" the firm tends to release procure orders one at a time to the retailer. Flexibility means offering a wide range of products and services and being able to adjust to the uncertainty of demand for the product offered. Flexibility has different meanings for different managers and several perfectly legitimate alternative paths exist towards flexible manufacturing (Beamon, 1999). Beamon (1999) highlighted various measures for flexibility in production systems. Slack (1991) defines system flexibility as the flexibility of the whole process.

3.2.13 Range of product and services

Companies that produce a wide range of products are expected to launch the latest technologies/products more gradually than companies with a narrower assortment of goods (Mapes *et al.*, 1997). Gunasekaran *et al.* (2004) reveals that a broad range of goods probably tend to perform less well in the areas of added values such as the number of workers, speed and delivery reliability. This clearly implies that the range of products affects the SCP. Fisher (1997) emphasized that the right selection of the SC approach depends upon the nature of the commodities, range, and product originality. The range of products and services also acts as an important strategic metric, and hence, it must be considered as a key factor for SCP (Gunasekaran *et al.*, 2001; Bhagwat and Sharma, 2007).

3.2.14 Flexibility of delivery systems to meet particular customer needs

Nowadays, delivery system processes are becoming more flexible to consumer needs and expectations. Good flexibility always benefits the decision of the end users thus it can be considered an important attribute for satisfying and holding on to customers. Novich (1990) notified that the delivery of customers' order can be grouped into diverse sections, and the kind of flexibility processes that persuades consumers to place orders is significant for attracting customers

(Bhagwat and Sharma, 2007). According to Cho *et al.* (2012), flexibility of the delivery system means flexibility of the service processes to meet various customer needs in terms of customer processing.

3.2.15 Effectiveness of delivery invoice methods

Invoice methods help in receiving goods or materials with the delivery date, time and the conditions. If the delivery invoice method is effective, then a product can be distributed effectively. This method determines if a product is delivered or not (Gunasekaran *et al.,* 2004). According to Bhagwat and Sharma (2007), areas of discrepancy can be identified to ensure zero faults in the delivery performance (Gunasekaran *et al.*, 2001).

3.2.16 On time delivery of goods

The most important measure of delivery performance is the delivery of the final product to the customer. On time delivery is one of the most important key factors of SCPM (Chao *et al.,* 1993; Aksoy and Ozturk, 2011). Stewart (1995) revealed that any delivery performance can probably be increased through a reduction in lead time attributes. On time delivery determines whether perfect delivery has taken place or not and measures the level of customer service (Gunasekaran *et al.,* 2004).

3.2.17 Delivery lead time

Delivery lead-time helps to increase the delivery performance of the SC (Stewart, 1995; Gelders *et al.,* 1994). Delivery lead-time reflects whether correct or faultless delivery has delivered on time or not (Hammamia and Freinb, 2013). Other attributes influence delivery performance such as transportation, frequency of delivery, delivery reliability etc.

3.2.18 Flexibility to meet particular customer needs

This is an essential factor for measuring the customer service performance in terms of customer demand. It includes product design, quality, delivery, reliability and flexibility to fulfil the customer needs (Bhagwat and Sharma, 2007; Roha *et al.,* 2013). In another way, this refers to accessibility and the capability to supply products and services that meet a particular customer's needs. According to Bower and Hout (1988), the flexibility of any system has a high impact on engaging consumers and provides a high level of awareness to the customers (Gunasekaran *et al.*, 2001).

3.2.19 Post transaction measures of customer service

Customer service performance, while it is not the last stage of a SC, provides services to the end user. This type of service is applied after the delivery of final product (Bruhn and Georgi, 2006; Xuea *et al.,* 2013). Customer service plays a significant role for both the customer's needs and satisfaction, and for feedback to advance the development of the SC (Gunasekaran *et al.*, 2004; Bhagwat and Sharma, 2007). The timely availability of spares help industries to improve consumer facilities/services, and buyers are also able to trace problems occurring from warranty claims.

3.2.20 Customer query time

This refers to the time it takes for an organization to reply to a customer's query with the necessary information or a corresponding delivery (Gunasekaran *et al.,* 2001; Bhagwat and Sharma, 2007; Beamon, 1999; Tewari and Misra, 2013). It is not unethical for customers to ask about the status of their order. This kind of information really helps both service providers and customers to plan their further activities, and helps the industry to retain them as customers (Bhagwat and Sharma, 2007; Gunasekaran *et al.*, 2001). Fast service and the right response to customers' query are crucial for keeping customers happy.

3.3 Research methodology

In this chapter, we have used interpretive structural modeling (ISM) for modeling and investigating the interrelationships among the key factors of SCPM because it uses experts' opinions from brainstorming sessions to develop contextual relationships. Moreover, it is widely known method, which is applicable in diverse fields and helps to classify and highlight relationships among the different factors (Warfield, 1974; Sage, 1977). There are two basic concepts to know regarding the ISM approach i.e., transitivity and reachability (Mudgal *et al.,* 2010). If variable x communicates to y and y communicates to z, then transitivity implies that variable x will necessarily communicate to z as shown in Figure 3.1. Transitivity is the basic theory in ISM and is always used in this modeling approach (Sharma *et al.,* 1995; Farris and Sage, 1975). The interrelationships among the different key factors of SCPM are achieved through the steps discussed by Ravi and Shankar (2005); Mudgal *et al.* (2010).

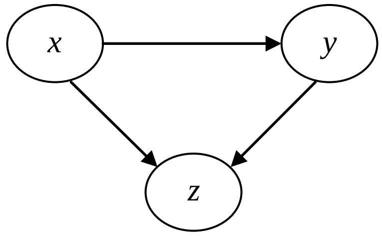

Figure 3.1: Concept of transitivity

Step 1: Key factors or variables affecting the system under consideration are listed, which can be actions, objectives and individuals etc. A survey of group problem solving techniques can be used for identifying key factors related to the defined problem.

Step 2: From the key factors identified in Step 1, an appropriate relationship is established between them with respect to which pairs of the key factors would be examined.

Step 3: A Structural Self-Interaction Matrix (SSIM) is developed from the key factors, which specifies pair-wise relations along with the key factors.

Step 4: An initial reachability matrix is developed from the SSIM and the matrix is checked for transitivity to arrive at the final reachability matrix.

Step 5: After obtaining the reachability matrix, next partitioned are done in order to find the hierarchy of each key factor.

Step 6: Next, a conical matrix is developed from the partitioned reachability matrix by a clubbing together of the key factors according to their position level.

Step 7: Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 8: Next, the resultant digraph is converted into an ISM, by replacing key factor nodes with statements.

Step 9: The ISM model developed in Step 8 is assessed for theoretical inconsistency, and essential changes are made.

The flow diagram for the structure of an ISM methodology is shown in Figure 3.2 (Mudgal *et al.*, 2010).

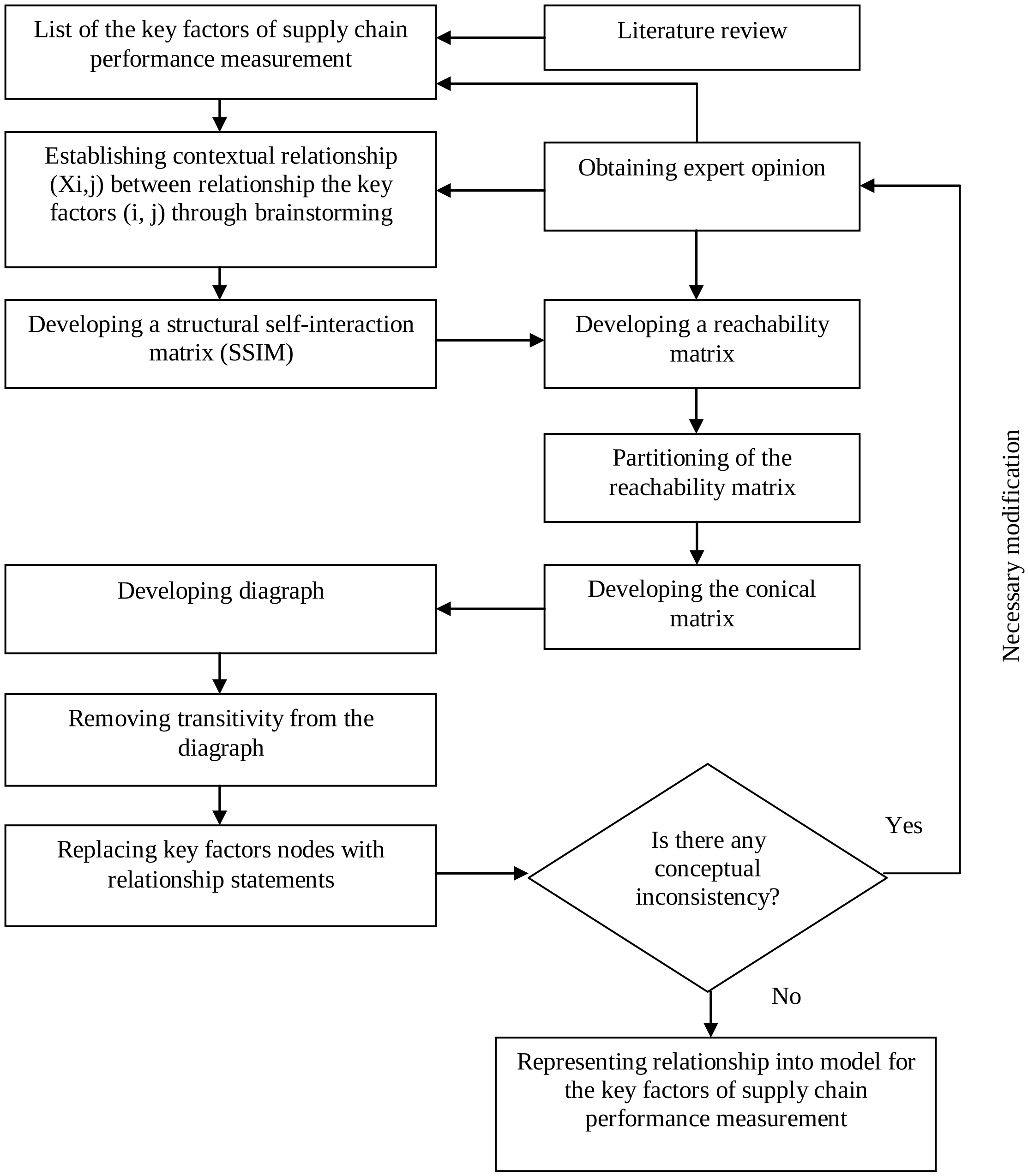

Figure 3.2: Flow chart for ISM methodology

3.4 ISM approach for modeling the key factors of SCPM

For developing the ISM-based model, various steps are followed and we have used twenty key factors to develop the model. The identification of key factors and their relative relationships guide the development of the different matrices. After developing a model, the key factors were classified into four clusters based on their driving and dependence power by using a fuzzy MICMAC analysis.

3.4.1 Structural self-interaction matrix (SSIM)

After identification of twenty key factors through a literature review and experts' opinions, the next step was to analyze these key factors. The contextual relationships between the key factors of SCPM are made by expert opinions in a brainstorming session. A group of experts was consulted from academia and industry. These experts had over 10-15 years of experience and were well familiar with the Indian automotive SC and their relationships. For analyzing the interrelationships among these key factors, an appropriate relationship of "leads to" type was chosen. Four symbols (V, A, X, O) are used for establishing the contextual relationship among the key factors and a structural self-interaction matrix (SSIM) was developed which is presented in Table 3.1.

V = If variable *x* influences variable *y*, A = If variable *x* is influenced by variable *y*,

X = If variables *x* and *y* influence each other, O = If variables *x* and *y* do not influence each other.

Table 3.1: Structural self-interaction matrix (SSIM)

S. No.	*Key Factors*	*20*	*19*	*18*	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
1	Quality	V	A	A	V	X	A	A	A	A	X	X	O	A	V	V	V	V	A	A	
2	Capacity utilization	V	A	A	V	V	A	X	A	A	V	V	V	A	V	V	V	V	A		
3	Buyer-supplier relationship	V	A	A	V	V	A	V	V	A	V	V	V	A	V	V	V	V			
4	On time delivery of goods	A	A	A	V	A	A	A	A	A	A	O	V	A	A	V	V				
5	Flexibility to meet particular customer needs	A	A	A	V	A	A	A	A	A	A	A	A	A	A	V					
6	Customer query time	A	O	A	A	A	A	A	A	A	A	A	A	A	A						
7	Flexibility of delivery systems to meet particular customer needs	V	A	A	V	A	A	A	A	A	A	A	V	A							
8	Supplier selection	V	A	V	O	V	A	V	V	A	V	V	V								
9	Delivery lead time	A	A	A	V	A	A	A	A	A	A	A									
10	Product cost	O	A	A	V	X	O	A	A	A	X										
11	Range of product and services	V	A	A	V	X	A	A	A	A											
12	Customer order path	O	A	V	O	V	A	V	V												
13	Mutual assistance in solving problems	V	A	A	V	V	A	V													
14	Effectiveness of master production schedule	V	A	A	V	V	A														
15	Order lead time	V	X	V	O	V															
16	Flexibility	V	A	A	V																
17	Post transaction measures of customer service	A	O	O																	
18	Purchase order cycle time	O	A																		
19	Order entry method	O																			
20	Effectiveness of delivery invoice methods																				

3.4.2 Development of reachability matrix

According to the theory of this model, the initial and final reachability matrixes from the SSIM are to be developed. Thus, SSIM needs to be transformed into binary numbers (i.e. 1s or 0s), which is called the initial reachability matrix (see Table 3.2). The given rules are used to substitute V, A, X, O of the SSIM matrix to get reachability matrix.

- If (x, *y*) entry in the SSIM is V then (*x*, *y*) entry in the reachability matrix will be 1 and (*y*, *x*) entry will be 0.
- If (*x*, *y*) entry in the SSIM is A then (*x*, *y*) entry in the reachability matrix will be 0 and (*y*, *x*) entry will be 1.
- If (*x*, *y*) entry in the SSIM is X then (*x*, *y*) entry in the reachability matrix will be 1 and (*y*, *x*) entry will also be 1.
- If (*x*, *y*) entry in the SSIM is O then (*x*, *y*) entry in the reachability matrix will be 0 and (*y*, *x*) entry will also be 0.

In the next sub-step, the final reachability matrix is achieved by incorporating the transitivity. The transitivity concept is introduced for this purpose, and some of the cells of the IRM are filled in by inference. Transitivity holds the relation between three elements, for example, if the relationship holds between the first and second, and the relationship holds between the second and third, then the relationship must necessarily hold between the first and third (i.e. $x > y$, $y > z$ then $x > z$). Thus, after incorporating the transitivity concept in Table 3.2, the final reachability matrix (FRM) is developed and is shown in Table 3.3. Moreover, the dependence and driving power of each key factor are calculated by summing up the number of 1's in the columns and rows respectively.

Table 3.2: Initial reachability matrix (IRM)

S. No.	*Key Factors*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
1	Quality	1	0	0	1	1	1	1	0	0	1	1	0	0	0	0	1	1	0	0	1
2	Capacity utilization	1	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1
3	Buyer-supplier relationship	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	1
4	On time delivery of goods	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
5	Flexibility to meet particular customer needs	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
6	Customer query time	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Flexibility of delivery systems to meet particular customer needs	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1
8	Supplier selection	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1
9	Delivery lead time	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
10	Product cost	1	0	0	0	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	0
11	Range of product and services	1	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	1
12	Customer order path	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0
13	Mutual assistance in solving problems	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	1
14	Effectiveness of master production schedule	1	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1
15	Order lead time	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1
16	Flexibility	1	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	1
17	Post transaction measures of customer service	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
18	Purchase order cycle time	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	0	1	0	0
19	Order entry method	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	0
20	Effectiveness of delivery invoice methods	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1

Table 3.3: Final reachability matrix (FRM)

Key Factors S. No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*Driving Power*
1	1	0	0	1	1	1	1	0	1*	1	1	0	0	0	0	1	1	0	0	1	*11*
2	1	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1	*13*
3	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	1	*15*
4	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	*5*
5	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	*3*
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
7	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	*7*
8	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1*	1	0	1	*17*
9	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	*4*
10	1	0	0	1*	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	1*	*11*
11	1	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	1	*11*
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1*	1	0	1*	*18*
13	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	1	*14*
14	1	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1	*13*
15	1	1	1	1	1	1	1	1	1	1*	1	1	1	1	1	1	1*	1	1	1	*20*
16	1	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	1	*11*
17	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	*2*
18	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1*	1	0	1*	*16*
19	1	1	1	1	1	1*	1	1	1	1	1	1	1	1	1	1	1*	1	1	1*	*20*
20	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	*6*
Dependence	*13*	*9*	*6*	*16*	*18*	*20*	*14*	*4*	*17*	*13*	*13*	*3*	*7*	*9*	*2*	*13*	*19*	*5*	*2*	*15*	

*Shows the transitivity

3.4.3 Partition of reachability matrix

After getting the FRM, partitions are made in order to find the hierarchy of each key factor. The level partitions of the different key factors are achieved by analyzing Table 3.4 and Table 3.5. The reachability set and antecedent set (Warfield, 1974) for each key factor is achieved from the FRM. The reachability set includes the key factor itself and another key factor that it might help to attain, whereas the antecedent set contains itself and other key factor that assist in getting it. After this, the intersection set is derived for all key factors based on the reachability set and the antecedent set. If the membership in the intersection set and reachability set are the same, then the highest priority is assigned in the hierarchy of the ISM model and that key factor is excluded from the following iteration. This process is repeated until the final iteration leads to the lowest level. Further, Table 3.4 explains the first iteration in which customer query time (key factor 6) is found at level I. Similarly, these processes are repeated till the level of each key factor is obtained. Results for iterations ii-xv are presented in Table 3.5.

3.4.4 Developing conical matrix

The development of the conical matrix is attained from the partitioned reachability matrix by clubbing together key factors according to their level, across the columns and rows of the final reachability matrix, which is used for developing the final diagraph and later the structural model. For example, key factor 17 is found at level II and key factor 13 at level X. Correspondingly, all the key factors were clubbed according to their level partition (see Table 3.6). Furthermore, the dependence power of a key factor is calculated by summing up the number of 1's in the columns and the driving power is calculated by summing up the number of 1's in the rows. Subsequently, ranks are calculated by giving the highest rank to the key factor that have the highest number of 1's in the rows and columns, which indicate the driving power and dependence power, respectively.

Table 3.4: Key factors level iteration *i*

Key Factors	*Reachability Set*	*Antecedents Set*	*Intersection Set*	*Level*
1	1,4,5,6,7,9,10,11,16,17,20	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	
2	1,2,4,5,6,7,9,10,11,14,16,17,20	2,3,8,12,13,14,15,18,19	2,14	
3	1,2,3,4,5,6,7,9,10,11,13,14,16,17,20	3,8,12,15,18,19	3	
4	4,5,6,9,17	1,2,3,4,7,8,10,11,12,13,14,15,16,18,19,20	4	
5	5,6,17	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,18,19,20	5	
6	6	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	6	***I***
7	4,5,6,7,9,17,20	1,2,3,7,8,10,11,12,13,14,15,16,18,19	7	
8	1,2,3,4,5,6,7,8,9,10,11,13,14,16,17,18,20	8,12,15,19	8	
9	5,6,9,17	1,2,3,4,7,8,9,10,11,12,13,14,15,16,18,19,20	9	
10	1,4,5,6,7,9,10,11,16,17,20	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	
11	1,4,5,6,7,9,10,11,16,17,20	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	
12	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,20	12,15,19	12	
13	1,2,4,5,6,7,9,10,11,13,14,16,17,20	3,8,12,13,15,18,19	13	
14	1,2,4,5,6,7,9,10,11,14,16,17,20	2,3,8,12,13,14,15,18,19	2,14	
15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	15,19	15,19	
16	1,4,5,6,7,9,10,11,16,17,20	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	
17	6,17	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	17	
18	1,2,3,4,5,6,7,9,10,11,13,14,16,17,18,20	8,12,15,18,19	18	
19	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	15,19	15,19	
20	4,5,6,9,17,20	1,2,3,7,8,10,11,12,13,14,15,16,18,19,20	20	

Table 3.5: Key factors level iteration *ii-xv*

Iteration	*Key Factors*	*Reachability Set*	*Antecedents Set*	*Intersection Set*	*Level*
ii	17	17	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20	17	*II*
iii	5	5	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,18,19,20	5	*III*
iv	9	9	1,2,3,4,7,8,9,10,11,12,13,14,15,16,18,19,20	9	*IV*
v	4	4	1,2,3,4,7,8,10,11,12,13,14,15,16,18,19,20	4	*V*
vi	20	20	1,2,3,7,8,10,11,12,13,14,15,16,18,19,20	20	*VI*
vii	7	7	1,2,3,7,8,10,11,12,13,14,15,16,18,19	7	*VII*
viii	1	1,10,11,16	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	*VIII*
viii	10	1,10,11,16	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	*VIII*
viii	11	1,10,11,16	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	*VIII*
viii	16	1,10,11,16	1,2,3,8,10,11,12,13,14,15,16,18,19	1,10,11,16	*VIII*
ix	2	2,14	2,3,8,12,13,14,15,18,19	2,14	*IX*
ix	14	2,14	2,3,8,12,13,14,15,18,19	2,14	*IX*
x	13	13	3,8,12,13,15,18,19	13	*X*
xi	3	3	3,8,12,15,18,19	3	*XI*
xii	18	18	8,12,15,18,19	18	*XII*
xiii	8	8	8,12,15,19	8	*XIII*
xiv	12	12	12,15,19	12	*XIV*
xv	15	15,19	15,19	15,19	*XV*
xv	19	15,19	15,19	15,19	*XV*

Table 3.6: Conical matrix

Key Factors S. No.	*6*	*17*	*5*	*9*	*4*	*20*	*7*	*1*	*10*	*11*	*16*	*2*	*14*	*13*	*3*	*18*	*8*	*12*	*15*	*19*	*Driving Power*
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
17	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*2*
5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*3*
9	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*4*
4	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*5*
20	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*6*
7	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	*7*
1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	*11*
10	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	*11*
11	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	*11*
16	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	*11*
2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	*13*
14	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	*13*
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	*14*
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	*15*
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	*16*
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	*17*
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	*18*
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	*20*
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	*20*
Dependence	*20*	*19*	*18*	*17*	*16*	*15*	*14*	*13*	*13*	*13*	*13*	*9*	*9*	*7*	*6*	*5*	*4*	*3*	*2*	*2*	

3.4.5 Development of digraph

Based on the conical form of the reachability matrix, an initial digraph including the transitivity links is obtained and generated by the nodes and lines of the edges. Relationship between two key factors is shown by an arrow from one key factor to another key factor. After confirming the hierarchy, an arrow is required to show the direction of the action. Similarly, a graph called a digraph is achieved after all the relationships (direct and indirect) are completed. Thus, a final diagraph is developed by removing the indirect links as shown in Figure 3.3. Based on the development process, top-level key factors are placed at the top of the diagraph and second level key factors are placed at second position and so on, until the bottom level is placed at the lowest position in the digraph.

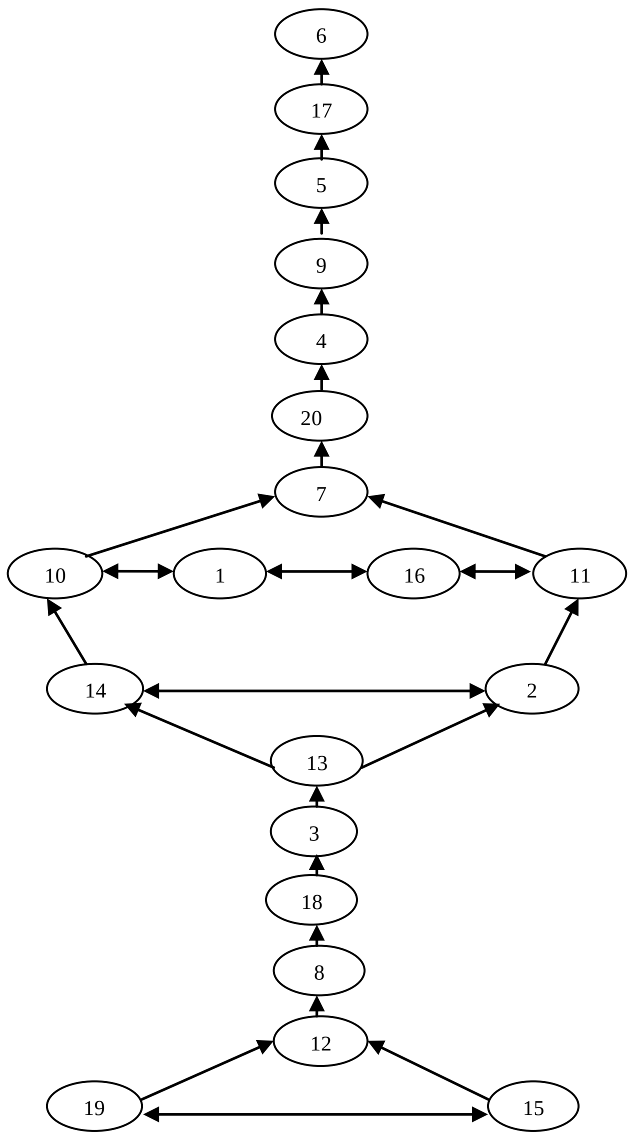

Figure 3.3: Levels of SCPM key factors

3.4.6 Building the ISM-based model

Next, the diagraph is transformed into an ISM-based model by replacing the nodes of the key factors with statements as depicted in Figure 3.4. Figure 3.4 explains that order entry method (key factor 19) and order lead time (key factor 15) are very important key factors in the Indian automotive SC as a hierarchy of ISM showing their position at the bottom level. Customer query time (key factor 6) secured the top position in the hierarchy, which means this key factor may influence the efficiency of SCP and the entire process of Indian automotive SC. Key factors 19 and 15 lead to the customer order path (key factor 12) and it will guide the supplier selection (key factor 8) towards SCPM. Similarly, supplier selection leads to the purchase order cycle time (key factor 18) and it leads to the buyer-supplier relationship (key factor 3). Supplier selection plays a crucial role in reducing costs and improving the quality of the products. A strong buyer-supplier relationship always benefits from mutual assistance for solving problems (key factor 13). A strong buyer-supplier relationship should be in position before assigning the effectiveness of a master production schedule (key factor 14) and capacity utilization (key factor 2) which would be counter to SCPM in the Indian automotive SC. Key factors 2 and 14 are interrelated and lead to product cost (key factor 10), quality (key factor 1), flexibility (key factor 16), and a range of products and services (key factor 11). These key factors will further help with the flexibility of delivery systems to meet particular customers' needs (key factor 7). Key factor 7 guides to other key factors that are at the top of the hierarchy such as the effectiveness of the delivery invoice methods (key factor 20), on time delivery of goods (key factor 4), delivery lead-time (key factor 9) and these key factors will further proceed to flexibility to meet the particular customer needs (key factor 5) and the post transaction measure of customer service (key factor 17). Without the support of all bottom side of key factors, it would be very difficult to fill all gaps of customers' query and their needs in a SC.

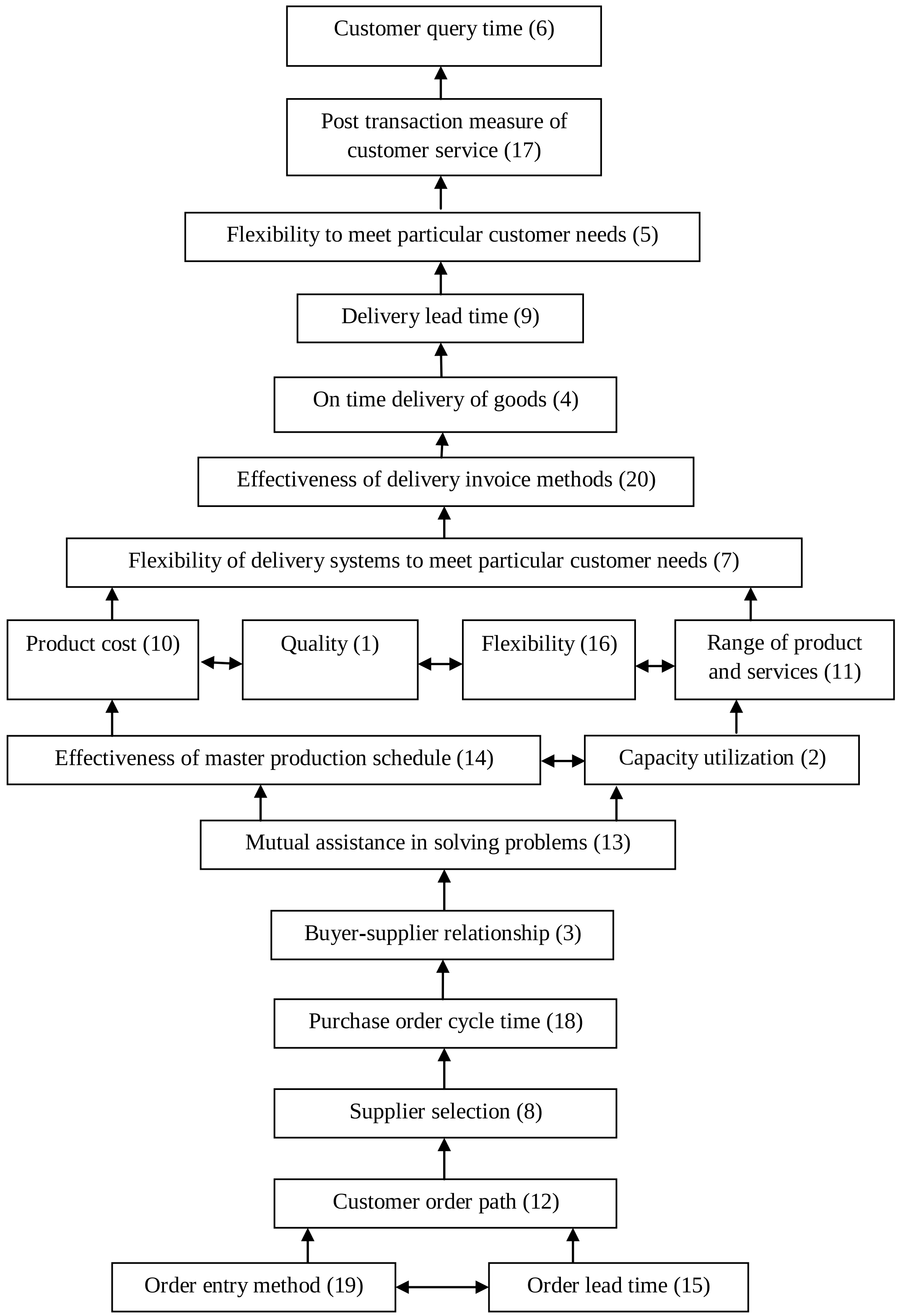

Figure 3.4: ISM-based model for SCPM key factors

3.5 Integration of ISM and fuzzy MICMAC

The direct and indirect relationships among the key factors for implementing SCPM across the Indian automotive supply chain were carried out by an ISM and fuzzy MICMAC. A direct relationship matrix is obtained by examining the direct relationships among the criterion in the ISM. Further, transitivity is ignored and the diagonal entries are converted into zero. Then a direct relationship matrix (DRM) is derived.

3.5.1 Fuzzy direct relationship matrix (FDRM)

Further analysis may be improved by considering the possibility of reachability instead of the mere consideration of reachability used so far. Usually, MICMAC considers only the binary type of relationships, so at this stage we have used a fuzzy set theory to increase the earlier sensitivity. By using the fuzzy MICMAC, an additional input of possibility of relations among the key factors is established. The possibility of relations can be defined by a qualitative consideration on 0 to 1 scale, which is given in Table 3.7 (Qureshi *et al.*, 2008).

Table 3.7: Fuzzy scale

Possibility of Reachability	No	Negligible	Low	Medium	High	Very High	Full
Value	0	0.1	0.3	0.5	0.7	0.9	1.0

The possibility of the numerical value of reachability is covered up on the DRM to obtain a fuzzy direct relationship matrix (FDRM). Further, the DRM is achieved by examining the direct relationship among the key factors in the digraph, disregarding the transitivity and making diagonal entries 0(zero). The DRM and FDRM are shown in Table 3.8 and Table 3.9 respectively.

3.5.2 Convergence of fuzzy direct relationship matrix

The FDRM is taken as a support to begin the procedure of finding the fuzzy indirect relationships between key factors. The matrix is multiplied or reproduced repeatedly up to a power until the hierarchies of the driving and dependence power are stabilized. This multiplication process follows the principle of fuzzy matrix multiplication (Zadeh, 1965), which is essentially a generalization of the Boolean matrix multiplication. According to the fuzzy set theory, when two fuzzy matrices are multiplied, the product matrix will also be a fuzzy matrix. Multiplication follows the rule given below: the product of fuzzy set A and fuzzy set B is fuzzy set C.

C = A, B, = maxk[min(a_{ik}, b_{kj})]   where, $A = (a_{ik})$ and $B = (b_{kj})$ are two fuzzy matrices

3.5.3 Stabilization of fuzzy matrix

As discussed in the previous part, the FDRM process and matrix multiplication stabilizes the matrix. The fuzzy stabilized matrix is given in Table 3.10. Further, the ranks are calculated by giving the highest ranks to the key factors with the highest number of 1's in the rows and columns, which indicate the driving power and dependence power, respectively. The purpose of this classification of the key factors is to analyze the driving and dependence powers of the key factors that influence the performance of the SC in the Indian automotive sectors.

Table 3.8: Direct relationship matrix (DRM)

S. No.	*Key Factors*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
1	Quality	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	1	1	0	0	1
2	Capacity utilization	1	0	0	1	1	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1
3	Buyer-supplier relationship	1	1	0	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	1
4	On time delivery of goods	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
5	Flexibility to meet particular customer needs	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
6	Customer query time	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Flexibility of delivery systems to meet particular customer needs	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1
8	Supplier selection	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	0	1	0	1
9	Delivery lead time	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
10	Product cost	1	0	0	0	1	1	1	0	1	0	1	0	0	0	0	1	1	0	0	0
11	Range of product and services	1	0	0	1	1	1	1	0	1	1	0	0	0	0	0	1	1	0	0	1
12	Customer order path	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	0
13	Mutual assistance in solving problems	1	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1
14	Effectiveness of master production schedule	1	1	0	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	0	1
15	Order lead time	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	1	1	1
16	Flexibility	1	0	0	1	1	1	1	0	1	1	1	0	0	0	0	0	1	0	0	1
17	Post transaction measures of customer service	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Purchase order cycle time	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	0	0	0	0
19	Order entry method	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0	0
20	Effectiveness of delivery invoice methods	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0

Table 3.9: Fuzzy direct relationship matrix (FDRM)

Key Factors S. No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*Sum*
1	0	0	0	0.3	0.3	0.7	0.3	0	0	0.9	0.5	0	0	0	0	0.3	0.7	0	0	0.3	4.3
2	0.5	0	0	0.5	0.5	0.5	0.7	0	0.5	0.3	0.5	0	0	0.5	0	0.7	0.1	0	0	0.1	5.4
3	0.7	0.5	0	0.7	0.5	0.3	0.7	0	0.5	0.3	0.5	0	0.7	0.5	0	0.7	0.3	0	0	0.3	7.2
4	0	0	0	0	0.5	0.7	0	0	0.7	0	0	0	0	0	0	0	0.5	0	0	0	2.4
5	0	0	0	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	1.6
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0.7	0.7	0.7	0	0	0.5	0	0	0	0	0	0	0	0.3	0	0	0.5	3.4
8	0.9	0.5	0.7	0.5	0.5	0.3	0.5	0	0.3	0.5	0.5	0	0.7	0.5	0	0.5	0	0.5	0	0.5	7.9
9	0	0	0	0	0.7	0.5	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	1.7
10	0.7	0	0	0	0.3	0.3	0.3	0	0.3	0	0.5	0	0	0	0	0.5	0.3	0	0	0	3.2
11	0.7	0	0	0.5	0.5	0.5	0.7	0	0.5	0.7	0	0	0	0	0	0.5	0.3	0	0	0.5	5.4
12	0.5	0.7	0.3	0.5	0.5	0.3	0.5	0.9	0.3	0.5	0.5	0	0.5	0.5	0	0.7	0	0.5	0	0	7.7
13	0.7	0.5	0	0.5	0.3	0.3	0.5	0	0.3	0.5	0.5	0	0	0.5	0	0.5	0.5	0	0	0.5	6.1
14	0.7	0.5	0	0.7	0.3	0.5	0.7	0	0.5	0.5	0.7	0	0	0	0	0.5	0.5	0	0	0.3	6.4
15	0.3	0.5	0.5	0.5	0.5	0.3	0.7	0.5	0.5	0	0.3	0.7	0.5	0.7	0	0.5	0	0.5	0.3	0.5	8.3
16	0.7	0	0	0.7	0.7	0.5	0.9	0	0.7	0.5	0.5	0	0	0	0	0	0.3	0	0	0.5	6
17	0	0	0	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
18	0.5	0.5	0.5	0.5	0.3	0.3	0.5	0	0.3	0.3	0.5	0	0.3	0.5	0	0.5	0	0	0	0	5.5
19	0.3	0.5	0.5	0.5	0.3	0	0.5	0.7	0.5	0.3	0.3	0.7	0.3	0.5	0.3	0.5	0	0.5	0	0	7.2
20	0	0	0	0.7	0.5	0.3	0	0	0.7	0	0	0	0	0	0	0	0.5	0	0	0	2.7
Sum	7.2	4.2	2.5	7.8	7.9	8.8	7.5	2.1	7.1	5.3	5.8	1.4	3	4.2	0.3	6.4	5.5	2	0.3	4	

Table 3.10: Fuzzy stabilized matrix

Key Factors S. No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*Sum*	*Rank*
1	0.5	0	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0	0	0.5	0.7	0	0	0.5	6.1	11
2	0.5	0	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0.5	0	0.5	0.7	0	0	0.5	6.6	8
3	0.7	0.5	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0.5	0	0.5	0.7	0	0	0.5	7.3	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
8	0.7	0.5	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0.5	0	0.5	0.7	0	0	0.5	7.3	3
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
10	0.5	0	0	0.5	0.5	0.5	0.5	0	0.5	0.5	0.5	0	0	0	0	0.5	0.5	0	0	0.5	5.5	13
11	0.7	0	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0	0	0.5	0.7	0	0	0.5	6.3	10
12	0.7	0.5	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0.5	0	0.5	0.7	0	0	0.5	7.3	3
13	0.7	0.5	0	0.5	0.5	0.7	0.5	0	0.5	0.5	0.5	0	0	0.5	0	0.5	0.5	0	0	0.5	6.9	6
14	0.7	0.5	0	0.5	0.5	0.7	0.5	0	0.5	0.7	0.5	0	0	0	0	0.5	0.7	0	0	0.5	6.8	7
15	0.7	0.5	0.3	0.5	0.5	0.7	0.5	0.3	0.5	0.7	0.5	0.3	0.3	0.5	0	0.5	0.7	0.3	0.3	0.5	9.1	1
16	0.7	0	0	0.5	0.5	0.7	0.5	0	0.5	0.5	0.5	0	0	0	0	0.5	0.5	0	0	0.5	5.9	12
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
18	0.5	0.5	0	0.5	0.5	0.5	0.5	0	0.5	0.5	0.5	0	0	0.5	0	0.5	0.5	0	0	0.5	6.5	9
19	0.7	0.5	0.3	0.5	0.5	0.7	0.5	0.3	0.5	0.7	0.5	0.3	0.3	0.5	0.3	0.5	0.7	0.3	0	0.5	9.1	1
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Sum	8.3	4	0.6	6.5	6.5	8.7	6.5	0.6	6.5	8.3	6.5	0.6	0.6	4	0.3	6.5	8.3	0.6	0.3	6.5		
Rank	2	12	14	5	5	1	5	14	5	2	5	14	14	12	19	5	2	14	19	5		

3.5.4 Fuzzy MICMAC analysis

The MICMAC method was developed by Duperrin and Godet (1973) to study the diffusion of impacts through reaction paths and loops for developing a hierarchy of key factors that can be used to identify and analyze different elements in a complicated system (Warfield, 1990). In addition, the MICMAC theory is based on the multiplication properties of matrices (Sharma *et al.*, 1995; Raj *et al.*, 2008). The purpose of the MICMAC analysis is to analyze the driving power and dependence of the variables (Mandal and Deshmukh, 1994; Faisal *et al.*, 2006). This study has integrated fuzzy with MICMAC, as Saxena *et al.* (1992) and Qureshi *et al.* (2008) stated in their study, that fuzzy MICMAC derived from the FDRM can be a big help since the significance of a criterion is measured less by its direct interrelationships and more by many indirect interrelationships. Indirect relationships between the key factors have an impact on the selection method through the influence of interactions in the form of chains and reaction loops. This is known as feedback. The Fuzzy set theory has been applied to each criterion in the traditional MICMAC for a possible reachability matrix based on dependence as well as driving power. In addition, the fuzzy MICMAC facilitates the critical investigation of each criterion. In a fuzzy MICMAC analysis, all the key factors are clustered into four categories, similar to a MICMAC analysis, of autonomous, dependent, linkage and independent (driver) key factors according to their categories (see Figure 3.5). The first cluster is comprised of the key factors that have a weak driving power and weak dependence, which are called 'autonomous factors'. These key factors are relatively disconnected from the system with only a few links, which may be strong. The second cluster portrays dependent key factors that have strong dependence but weak driving power, which are called dependent key factors. The third cluster includes the key factors that have a strong driving power as well as a strong dependence. These are called linkage key factors because they are unstable, in the sense that any action on these key factors will have an effect on others and a feedback on themselves. The fourth cluster contains key factors that have a strong driving power, however, a weak dependence that are called independent or driver key factors.

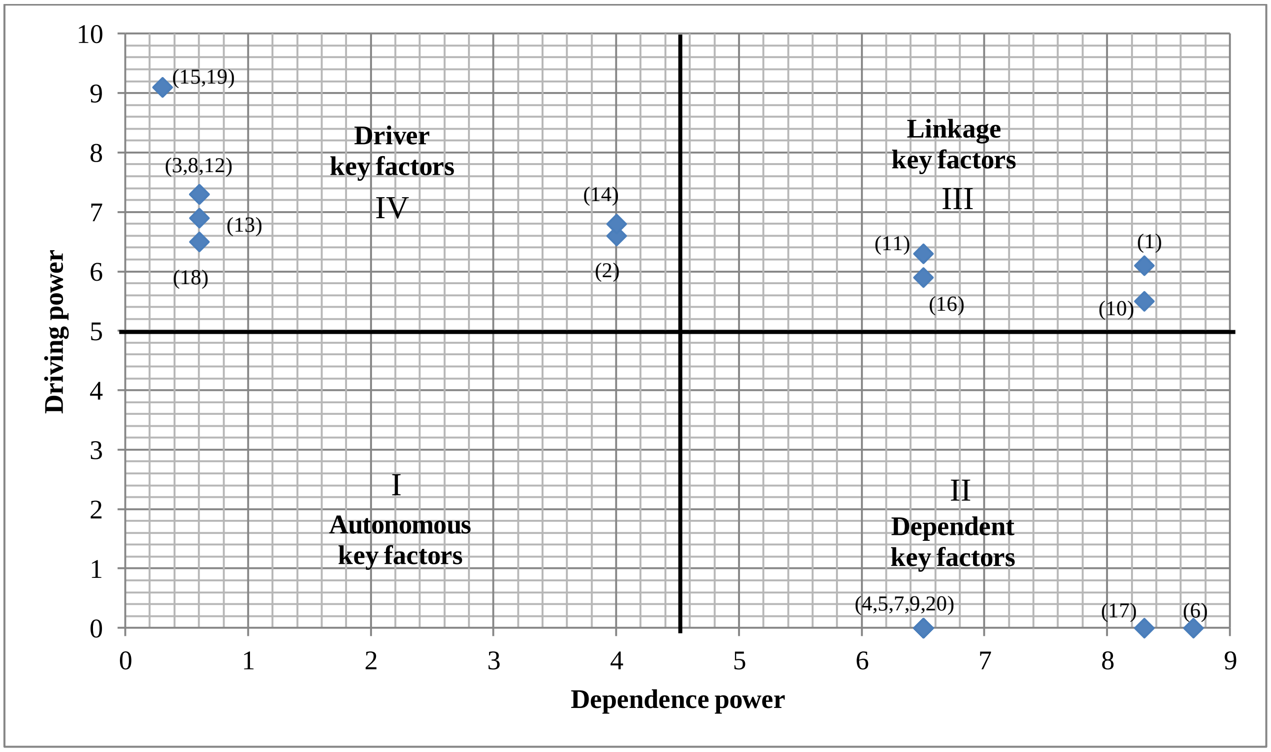

Figure 3.5: Driving power and dependence power diagram

3.6 Conclusion and managerial implications

The SCPM key factors used in this study are essential for the policy makers and managers to improve SCP in the Indian automotive industry. There may be a few hidden key factors in any SC, thus this study describes twenty key factors and explores the relationships among them. These key factors are identified based on literature review and a brainstorming session. The purpose of the brainstorming session was to identify the key factors of SCPM and developing a relationship matrix as a first step towards building the ISM-based model. The relationships among the key factors were explored using the ISM approach. The key factors identified in this study are helpful in measuring the SCP of the Indian automotive firms. The driving and dependency power are calculated (see Figure 3.5) using fuzzy MICMAC analysis. Figure 3.4 provides valuable suggestions for the top management of automotive firms about the significance of the key factors.

The results provided in Figure 3.4 show that the order entry method (key factor 19) and order lead-time (key factor 15) are significant key factors, showing a higher driving power at the bottom of the hierarchy. Therefore, top management should focus on these key factors to make an effective and efficient SC. These results may useful for the firm’s management in order to rethink their business strategy. It is evident from Figure 3.5 that there is no autonomous key factor, which suggests that all the considered key factors influence SCP in the Indian automotive industry.

It is also observed that customer query time (key factor 6), post-transaction measure of customer service (key factor 17), flexibility to meet particular customer needs (key factor 5), delivery lead time (key factor 9), on-time delivery of goods (key factor 4), effectiveness of delivery invoice methods (key factor 20), and flexibility of the delivery systems to meet particular customer needs (key factor 7) are weak key factors. However, they have a strong dependence on other key factors such as the order entry method (key factor 19), order lead time (key factor 15), customer order path (key factor 12), supplier selection (key factor 8), purchase order cycle time (key factor 18), buyer-supplier relationship (key factor 3), mutual assistance in solving problems (key factor 13), effectiveness of master production schedule (EMPS), and capacity utilization (CU). These key factors represent the awareness related to SCPM with a high support of buyer's strategy or planning performance as well as supplier's involvement, as shown in Figure 3.4. Figure 3.5 also indicates that there are four linkage key factors i.e., product cost (key factor 10), quality (key factor 1), flexibility (key factor 16), and range of product and services (key factor 11). These connect the driving key factors with the dependent key factors. The linkage key factors are derived from the absolute driving key factors and are the result of absolute dependent key factors. Only seven key factors are weak drivers and are more dependent on others. Nine key factors have the least amount of dependence but a strong driving power. Thus, these are root key factors and management should focus on these key factors as an initiative to improve their SCP. Some important key factors were uncovered in this study and put into an ISM model to explore the relationships among them. In this chapter, a model is developed to explore the key factors for SCPM in the Indian automotive industry. However, it is more generalized in nature, so it can also be utilized in other industry.

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CHAPTER 4

Modeling the Barriers of the Indian Automotive Supply Chain Performance Measurement

Preview

The previous chapter was related to key factors of supply chain performance measurement (SCPM) in the Indian automotive industry and explored the relationships between them. But, the objective of this chapter is to explore the interactions among the barriers of SCPM in the Indian automotive industry. The Indian automotive industries are facing several issues in SCPM due to various constraints. These constrains act like a barrier of SCPM. This chapter first identifies the different barriers that affect SCP based on literature review and experts' opinion and then explores the mutual relationships among the barriers using an interpretive structural modeling (ISM) with a fuzzy cross-impact matrix multiplication applied to classification (fuzzy MICMAC) approach. The results indicate that the lack of awareness related to SCP measurement system in supply chain is a very critical barrier. Finally, various strategies are suggested for the managers to remove the dominant barrier that affect SCP.

4.1 Introduction

In today's business environment, supply chain management (SCM) is a key strategic factor for many organizations to increase their efficiency and remain competitive in market (Gunasekaran *et al.,* 2001). Supply chain (SC) logistics performance was probably one of the first attempts to define SCP (Chow *et al.,* 1994; Gunasekaran and Kobu, 2007; Chia *et al.,* 2009). The performance of SC affects the overall performance of a system (Gunasekaran and Kobu, 2007; Ganga and Carpinetti, 2011) and a unique attribute of SCPM is that it measures the interdependencies that cross the borders of firms (Beamon, 1999; Gunasekaran *et al.,* 2001; 2004; Shepherd and Gunter, 2006). Performance measurement (PM) is a process of measuring the efficiency and effectiveness of SC based on past actions (Kaplan and Norton, 1992; Beamon, 1999; Neely *et al.,* 2002; Shepherd and Gunter, 2006). Choy *et al.* (2007) developed a system to evaluate the performance of associated suppliers using a benchmarking structure. Several theories of SCPM are discussed in literature (Brewer and Speh, 2000; Park *et al.*, 2005; Yeh *et al.*, 2007). Gunasekaran *et al.* (2004) proposed a framework for SCPM at the operational, tactical and strategic levels. Charan *et al.* (2008) indicated that a better SCPM system boosts a strong relationship among the SC members. In today's business environment, a long-term relationship among the different partners of SC is the need of the hour. Though, many Indian organizations have realized the importance of extended SC and use of new technologies. However, only few Indian automotive companies have effective strategies for SCPM.

The reason behind considering the Indian automotive industry in this study is that it is one of the fastest growing sectors in India. It is one of the key drivers for economic growth as it has more than 10% contribution to the Indian GDP (Burange and Yamini, 2008; Automotive Mission Plan, 2006). In the recent time, many reputed International manufacturing companies such as Honda, Ford, Volkswagen, and Toyota etc. have opened their manufacturing plants in the India because they not only see the India as emerging market but also see it as an efficient supplier base (Burange and Yamini, 2008). Many global auto assemblers are considering the Indian auto parts firms as their SC partners (Joshi *et al.*, 2013).

Nowadays most of the firms consider SC as a tool to compete in market (Christopher and Towill, 2001; Charan *et al.,* 2008). Therefore, it is imperative to develop a system for improving SCP (Chen and Paulraj, 2004; Sharma and Bhagwat 2007). Gunasekaran and Kobu (2007) stated that one of the major challenges before the top management is to develop appropriate measures for SCP. In some instances these measures create different obstacles in achieving effective SC process and these obstacles are called as barriers. These barriers not only create problems in operations process but also influence each other's. Therefore, it is necessary to explore the mutual relationships among these barriers (Wang *et al.*, 2008).

The top management of the automotive industry need to identify and remove these barriers to make their SC more effective and efficient (Mudgal *et al.,* 2010). Saad and Patel (2006) are the frontrunners to study the structure of SCP measures and the difficulty of implementing such measures in the Indian automotive industry. They have identified that most of the Indian automotive companies are not implementing the different ideas of SCP effectively. There is dearth of studies that precisely focus on the classification of the barriers that affect implementation of SCPM system in the Indian automotive industry.

This study makes an attempt to fill this gap in the literature in the following ways. We first identify different barriers that affect SCP in the Indian automotive industry based on literature review and experts' brainstorming sessions. Further, we investigate the interrelationships among these barriers. Finally, an integrated ISM technique (Warfield, 1974) with fuzzy MICMAC (Duperrin and Godet, 1973; Qureshi *et al.*, 2008) was utilized to categorize the barriers according to their driving and dependence power.

The remainder of this chapter is organized as follows. Section 4.2 discusses the identified barriers related to Indian automotive supply chain. Section 4.3 demonstrates the research methodology of this objective. The ISM approach for modeling the barriers is illustrated in section 4.4. Section 4.5 discusses the integrated ISM and fuzzy MICMAC approach to drive the dependence and driving power of the barriers. Conclusion and managerial implications are discussed in Section 4.6.

4.2 Identifying barriers of the Indian automotive SCPM

In this section, a thoroughly literature review is provided related to SCPM. The barriers identified based on the literature review and experts' opinions are discussed below in detail.

4.2.1 Lack of awareness related to SCP measurement system

The lack of awareness related to SCPM system is one of the major barrier in the Indian automotive industry and employees must be aware about SCPM system (Charan *et al.*, 2009). Wang *et al.* (2008) indicated that the awareness of any system related to PM is very important but many firms ignore it due to the lack of relevant policies, funding, and other issues. Moreover, awareness related to SCPM system not only provides direct benefits to the firm but also promotes the top management.

4.2.2 Inadequate strategic planning

A better strategy assists companies to increase their performance and also identifies long-term goals. Mudgal *et al.* (2010) discovered that strategic planning is necessary, as it provides positive supports to measure performance incessantly. In the current scenario, there is a need to put more focus on better strategic planning due to the rapid increase in demand of the innovative products. Furthermore, strategic planning and proper scheduling are very crucial to achieve goals of any organization (Wang *et al.*, 2008; Joshi *et al.*, 2013; Muduli *et al.*, 2013).

4.2.3 Lack of top management dedication

Commitment and dedication from the top management is a significant factor for strategic planning and decision making (Hamel and Prahalad, 1989; Zhu and Sarkis, 2007). The support and involvement of the top management help the organization to built effective and efficient SC. Moreover, implementation of the strategic and action plans requires constant supports of the top management (Ravi and Shankar, 2005; Muduli *et al.*, 2013).

4.2.4 Lack of trained manpower

Another significant barrier in the automotive industry is the lack of trained manpower the untrained manpower, lack of ability for testing, and lack of technical support have significant effect on building an effectiveness of SCPM system (Andrews-Speed, 2004). The existing manpower must be given continuous training regarding the use and adoption of new technologies in system (Wang *et al.*, 2008). Ravi and Shankar (2005) found that training and education are one of the major needs for measuring the effectiveness of SC in any organization.

4.2.5 Disinclination of the support from distributors, retailers and dealers

Poor' commitment from the suppliers or a lack of support from the distributors/customers/dealers can drops the trust level among the SC members. The low trust between SC members can spoil the entire SC process of any firms (Kumar and Banerjee, 2014). A lack of commitment from the any members of SC may affect the overall SCP (Sarkar and Mohapatra, 2006).

4.2.6 Inefficient information and technology system

To improve the performance of an automotive firm, management must be aware of the obstacles that serve as barriers to the firm's performance. Information and technology systems play an important role in each and every business activities (Cho *et al.*, 2009). Therefore, one of the major tasks before organizations is to use efficient information and technology systems at the different stages of SC (Wang *et al.*, 2008). It is evident from various studies that the adoption of new information and technology system increases collaboration among the different SC partners and also helps in implementing SCPM system (Rogers and Tibben-Lembke, 1998; Charan *et al.*, 2009; Luthra *et al.*, 2011).

4.2.7 Lack of appropriate implementation of SCP measurement system

SCPM initiative is the most suitable idea to improve the system's performance (Gunasekaran *et al.*, 2004). Ren *et al.* (2004) indicated that implementation and appropriate use of SCPM system plays a significant role in improving the overall performance of a system. Saad and Patel (2006) have found that implementation of SCPM system has not provided very fruitful results in the Indian context due to various barriers. Therefore, the hitches arise in implementing the SCPM system is one of the barriers for SCP (Ravi and Shankar, 2005).

4.2.8 Encroaching market competition and uncertainty in demand

Customer is the heart of any business and no business can sustain without the involvement of its customers. Current market scenario is very uncertain due to the global competition and high volatile customers demand (Yu Lin, 2007). Nowadays, most of the SCs are customers oriented and to fulfil the customers demand, the firms face many challenges at different levels of the SC (i.e., the manufacturing process, delivery process, manpower and financial etc.). For any business, unfulfilled demand of the customer acts as a significant barrier to SCP (Mudgal *et al.*, 2010).

4.2.9 Lack of appropriate production technology adoption

Technology brings ample awareness of the system and there is a lack of resources for new technologies in the Indian companies. Very few Indian automotive firms have a full-fledged research and development department. A firm with experience on the tools and techniques and adoption of relevant technologies will have higher capacity (Gant, 1996; Wang *et al.*, 2008). Luthra *et al.* (2011) emphasized that resistance to technological innovation is a major barrier for the Indian automotive firms.

4.2.10 Lack of support from government systems

The lack of support from the government is other obstacles for the Indian automotive firms. The government bodies may encourage or discourage the firms to implement a better SC in terms of adoption of new technology, policies for workers, taxes, and environmental rules and regulations (Scupola, 2003). The government policies significantly influence the overall SC competitiveness of the Indian automotive companies (Gunasekaran *et al.*, 2004; Singh *et al.*, 2007; Joshi *et al.*, 2013).

4.2.11 Lack of consistency in business capability between buyers and suppliers

Miscommunication, lack of commitment, lack of interest, lack of trust and inconsistency between the traders are major problems that affect different processes of SC (Moberg *et al.*, 2003; Welch and Wietfeldt, 2005; Sarkar and Mohapatra, 2006). Many suppliers do not believe in becoming dedicated for different business practices as it is not profitable for them (Wang *et al.*, 2008). Informal relations and improved communication can help both parties and therefore, both partners need to maintain a positive business relationship that will increase the level of trust between them (Yu Lin and Hui Ho, 2008; Meena and Sarmah, 2012).

4.2.12 Dispersed IT infrastructure

Some researchers (Monczka and Morgan, 1997; Kilpatrick and Factor, 2000; Bender, 2000) indicated that a dispersed information technology infrastructure is a prominent barrier to SC integration. According to Mudgal *et al.* (2010), information technology supports increases business communications and brings more effectiveness in a system. A dispersed information technology infrastructure and poor communication causes various difficulties in implementation of SC process (Gunasekaran *et al.*, 2004; Lohman *et al.*, 2004; Singh *et al.*, 2007; Joshi *et al.*, 2013).

4.2.13 Lack of funding or financial constraints

Financial constraints is another significant barrier in the Indian automotive SC. Wang *et al.* (2008) stated that funding is one of the primary challenge in adoption of high technology/tools/equipment/machinery for any organization. Most of the small Indian automotive firms including few large firms are facing this issue (Jharkharia and Shankar, 2006). The poor financial position of firms and lower level of government support are one of the main reasons behind this issue. Moreover, cost is another major barrier for manufacturing firms (Min and Galle, 2001; Ravi and Shankar, 2005; Orsato, 2006; Walker *et al.*, 2008; Mudgal *et al.*, 2010).

4.2.14 Destitute quality of human resource

The poor quality of human resources is one significant barrier for the Indian automotive firms (Mathiyazhagan *et al.*, 2013). Although, by providing better training and education this problem can be resolved (Luthra *et al.*, 2011). The quality of human resources provides novel ideas for organizations, such as exposure to new technologies and helps in latest technology implementation (Hillary, 2000; Thompson, 2002; Perron, 2005; Yu Lin and Hui Ho, 2008). However, due to the financial limitation, the quality of human resources may be considered as a barrier. The list of all barriers with their sources has been presented in Table 2.5 (see Chapter 2).

4.3 Research methodology

We have consulted experts from the Indian automotive firms for conducting brainstorming sessions to identify the barriers and to set up their mutual relationships. Total sixteen experts are considered who are working at managerial level and have minimum of ten years of experience in SCM area. The barriers identified from the literature related to SCPM were distributed among the experts panel to understand the relevance of these barriers in automotive SC. All the experts were free to add or subtract any barrier identified from the literature. At the end, fourteen barriers related to SCPM were finalized and the experts were then asked to establish the interrelationship among the barriers.

Saxena *et al.* (1992) applied an ISM approach to identify the key variables and developed a direct relationship matrix among these variables in the Indian cement industry. Charan *et al.* (2008), Luthra *et al.* (2011) and Muduli *et al.* (2013) used similar approach in SCM. The successfully applications of the ISM methodology in the aforementioned and other studies have emanated us to utilize it for exploring the relationships among the barriers. ISM is an excellent tool that helps to identify and know the relationships among the specific variables or items (Warfield, 1974; Sage, 1977) and can be applied in different fields. There are two basic concepts of the ISM approach namely (i) transitivity, and (ii) reachability (Farris and Sage, 1975; Sharma *et al.*, 1995; Raj *et al.*, 2008). Transitivity can be explained with the following example. If variable *i* is related to *j* and *j* is related to *k*, then transitivity implies that variable *i* is necessarily related to *k*, then transitivity implies that variable *i* is necessarily related to *k*. Figure 4.1 shows the transitivity relation. A flow diagram for the structure of an ISM methodology is shown in Figure 4.2 (Mudgal *et al.*, 2010).

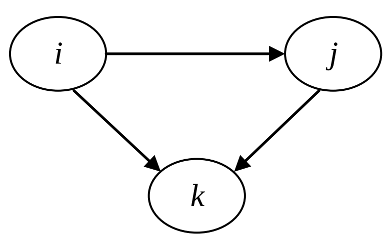

Figure 4.1: Concept of transitivity

The various steps involved in the ISM methodology by Ravi and Shankar (2005); Mudgal *et al.* (2010) are represented as follows:

Step 1: Barriers affecting the system under consideration are listed. A survey or group problem solving techniques can be used to identify variables related to the defined problem.

Step 2: From the barriers identified in Step 1, an appropriate relationship is established between barriers with respect to which pairs of the barriers would be examined.

Step 3: A Structural Self-Interaction Matrix (SSIM) is developed from the barriers, which specifies pair-wise relations along with the barriers.

Step 4: An initial reachability matrix is developed from the SSIM and the matrix is checked for transitivity to arrive at the final reachability matrix.

Step 5: After obtaining the reachability matrix, next partitioned are done in order to find the hierarchy of each barrier.

Step 6: Next, a conical matrix is developed from the partitioned reachability matrix by a clubbing together of barriers according to their position level.

Step 7: Based on the above given relationships in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 8: Next, the resultant digraph is converted into an ISM-based model, by replacing barrier nodes with statements.

Step 9: The ISM model developed in Step 8 is assessed for theoretical inconsistency, and essential changes are made.

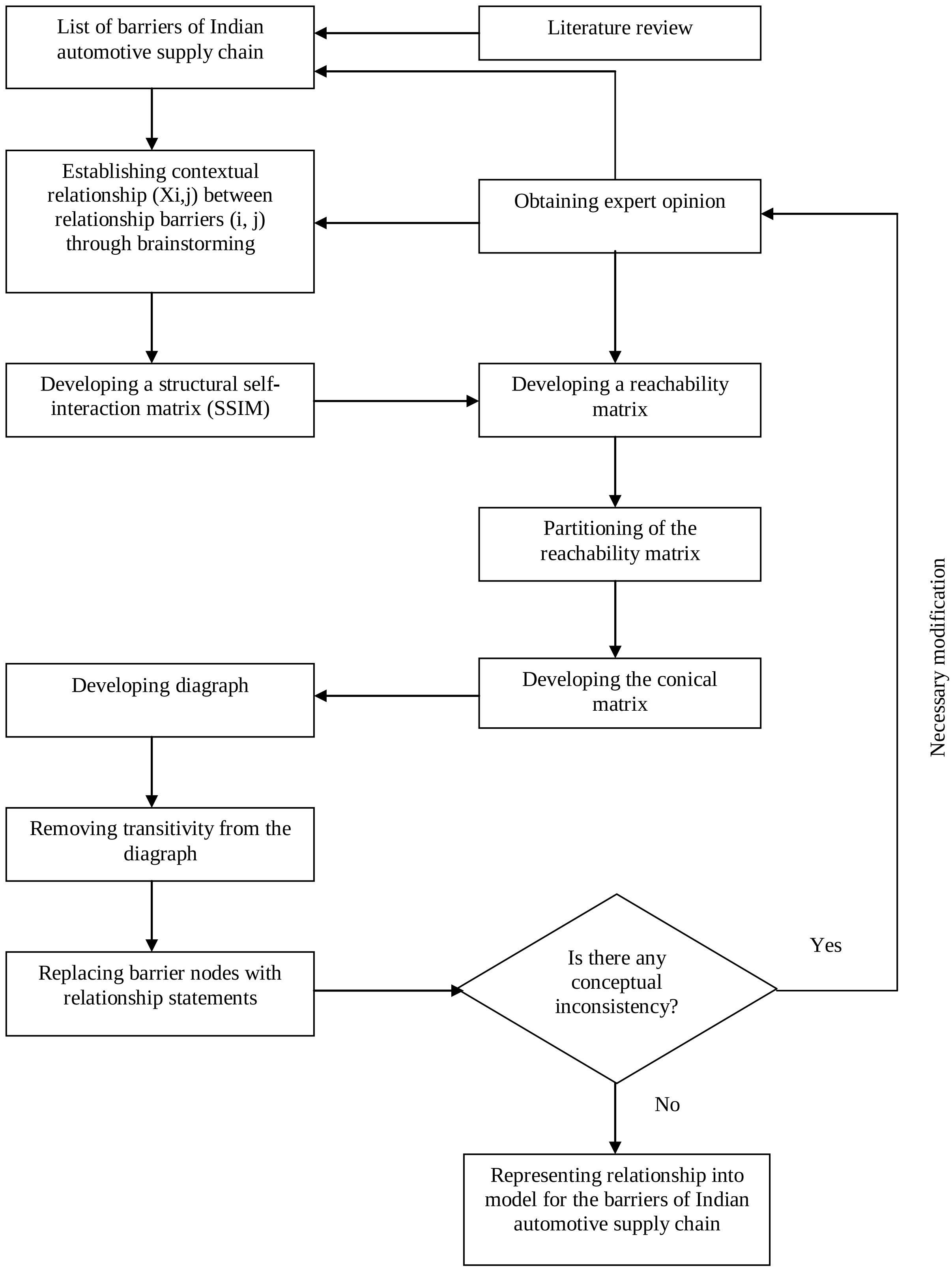

Figure 4.2: Flow chart for ISM methodology

4.4 ISM approach for modeling the barriers of SCPM

This study considers fourteen barriers to develop an ISM model. These barriers are classified based on their dependence and driving power using a fuzzy MICMAC analysis.

4.4.1 Structural self-interaction matrix (SSIM)

After identification of the fourteen barriers through literature review and experts' opinions, the next step is to analyze these barriers. Experts suggested that good contextual relationships among barriers can be achieved using brainstorming technique. Therefore, a group of experts from both the industry and academia were consulted to explore the appropriate relationships among the barriers in the Indian automotive SC. These experts have 10-15 years of experience and are familiar with implementation of SCPM system. For analyzing the interrelationships among these barriers, a contextual relationship of "leads to" type is chosen. This means that one barrier can help alleviate another barrier. Based on this, a contextual relationship is developed between any two barriers (*i* and *j*) (Barve *et al.*, 2009). Four symbols (V, A, X, O) are used to establish the contextual relationship between the barriers.

V = Barrier *i* will help to achieve barrier *j*; A = Barrier *j* will help to achieve barrier *i*;

X = Barrier *i* and *j* will help to achieve each other; O = Barrier *i* and *j* are unrelated.

Based on the contextual relationships, a structural self interaction matrix (SSIM) is developed with the help of the fourteen barriers to implement SCP. The structural self interaction matrix is depicted in Table 4.1.

Table 4.1: Structural self-interaction matrix (SSIM)

S. No.	*Barriers*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
1	Lack of awareness related to SCP measurement system	V	V	V	V	O	V	V	V	V	V	V	V	V	
2	Inadequate strategic planning	A	X	V	V	V	V	V	O	V	V	V	A		
3	Lack of top management dedication	X	V	V	V	V	V	O	O	V	V	V			
4	Lack of trained manpower	A	A	X	A	O	A	O	A	V	V				
5	Disinclination of the support from distributors, retailers and dealers	A	A	A	A	A	A	V	A	A					
6	Inefficient information and technology system	A	A	X	A	A	A	V	A						
7	Lack of appropriate implementation of SCP measurement system	A	A	V	V	A	A	V							
8	Encroaching market competition and uncertainty in demand	A	O	O	A	O	A								
9	Lack of appropriate production technology adoption	A	A	O	V	A									
10	Lack of support from government systems	O	V	V	V										
11	Lack of consistency in business capability between buyers and suppliers	A	A	V											
12	Dispersed IT infrastructure	A	A												
13	Lack of funding or financial constraints	A													
14	Destitute quality of human resource														

4.4.2 Development of the initial and final reachability matrix

Based on the model, an initial reachability matrix and final reachability matrix are developed by transforming SSIM into binary digits (i.e. 1s or 0s) called initial reachability. The following rules (Barve *et al.*, 2009) are used to substitute V, A, X, O of SSIM to get reachability matrix.

- If the (*i*, *j*) entry in the SSIM is V, then (*i*, *j*) entry in the reachability matrix becomes 1 and (*j*, *i*) entry becomes 0.
- If the (*i*, *j*) entry in the SSIM is A, then (*i*, *j*) entry in the reachability matrix becomes 0 and (*j*, *i*) entry becomes 1.
- If the (*i*, *j*) entry in the SSIM is X, then (*i*, *j*) entry in the reachability matrix becomes 1 and (*j*, *i*) entry becomes 1.
- If the (*i*, *j*) entry in the SSIM is O, then (*i*, *j*) entry in the reachability matrix becomes 0 and (*j*, *i*) entry becomes 0.

The initial reachability matrix for the barriers is shown in Table 4.2. Further, sub-step for the final reachability matrix (see Table 4.3) which is obtained by incorporating the transitivity in Table 4.2. The dependence and driving power of each barrier are also presented in Table 4.3. The driving power and dependence power are calculated using fuzzy MICMAC in the next section, where the barriers are classified into four clusters such as autonomous, dependent, linkage, and driver.

Table 4.2: Initial reachability matrix (IRM)

S. No.	*Barriers*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	Lack of awareness related to SCP measurement system	1	1	1	1	1	1	1	1	1	0	1	1	1	1
2	Inadequate strategic planning	0	1	0	1	1	1	0	1	1	1	1	1	1	0
3	Lack of top management dedication	0	1	1	1	1	1	0	0	1	1	1	1	1	1
4	Lack of trained manpower	0	0	0	1	1	1	0	0	0	0	0	1	0	0
5	Disinclination of the support from distributors, retailers and dealers	0	0	0	0	1	0	0	1	0	0	0	0	0	0
6	Inefficient information and technology system	0	0	0	0	1	1	0	1	0	0	0	1	0	0
7	Lack of appropriate implementation of SCP measurement system	0	0	0	1	1	1	1	1	0	0	1	1	0	0
8	Encroaching market competition and uncertainty in demand	0	0	0	0	0	0	0	1	0	0	0	0	0	0
9	Lack of appropriate production technology adoption	0	0	0	1	1	1	1	1	1	0	1	0	0	0
10	Lack of support from government systems	0	0	0	0	1	1	1	0	1	1	1	1	1	0
11	Lack of consistency in business capability between buyers and suppliers	0	0	0	1	1	1	0	1	0	0	1	1	0	0
12	Dispersed IT infrastructure	0	0	0	1	1	1	0	0	0	0	0	1	0	0
13	Lack of funding or financial constraints	0	1	0	1	1	1	1	0	1	0	1	1	1	0
14	Destitute quality of human resource	0	1	1	1	1	1	1	1	1	0	1	1	1	1

Table 4.3: Final reachability matrix (FRM)

S. No.	*Barriers*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*Driving Power*
1	Lack of awareness related to SCP measurement system	1	1	1	1	1	1	1	1	1	1*	1	1	1	1	14
2	Inadequate strategic planning	0	1	0	1	1	1	1*	1	1	1	1	1	1	0	11
3	Lack of top management dedication	0	1	1	1	1	1	1*	1*	1	1	1	1	1	1	13
4	Lack of trained manpower	0	0	0	1	1	1	0	1*	0	0	0	1	0	0	5
5	Disinclination of the support from distributors, retailers and dealers	0	0	0	0	1	0	0	1	0	0	0	0	0	0	2
6	Inefficient information and technology system	0	0	0	1*	1	1	0	1	0	0	0	1	0	0	5
7	Lack of appropriate implementation of SCP measurement system	0	0	0	1	1	1	1	1	0	0	1	1	0	0	7
8	Encroaching market competition and uncertainty in demand	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
9	Lack of appropriate production technology adoption	0	0	0	1	1	1	1	1	1	0	1	1*	0	0	8
10	Lack of support from government systems	0	1*	0	1*	1	1	1	1*	1	1	1	1	1	0	11
11	Lack of consistency in business capability between buyers and suppliers	0	0	0	1	1	1	0	1	0	0	1	1	0	0	6
12	Dispersed IT infrastructure	0	0	0	1	1	1	0	1*	0	0	0	1	0	0	5
13	Lack of funding or financial constraints	0	1	0	1	1	1	1	1*	1	1*	1	1	1	0	11
14	Destitute quality of human resource	0	1	1	1	1	1	1	1	1	1*	1	1	1	1	13
	Dependence	1	6	3	12	13	12	8	14	7	6	9	12	6	3	

* Shows the transitivity

4.4.3 Partition of reachability matrix

After driving the final reachability matrix, first partitions are done to find the level of each barrier and then a conical matrix is generated which is explained subsequently. The reachability set and antecedent set for each barrier can be attained from the final reachability matrix (Warfield, 1974; Barve *et al.*, 2009; Muduli *et al.*, 2013). Later, the intersection set of one specific barrier is derived from the intersection of its reachability set and antecedent set (Diabat and Govindan, 2011; Muduli *et al.*, 2013). If the membership in reachability set and the intersection set are same then the first or top priority is assigned to ISM hierarchy and the barrier is expelled from the subsequent iteration. This process leads to a final iteration leading to the bottom level. The first-level barriers are those barriers that will not lead the other barriers over their own level in the hierarchy. Table 4.4 illustrations the first iteration where the encroaching market competition and uncertainty in demand (Barrier 8) is found at level I. Similar iterations are repeated till the level of each barrier is obtained. The results for iterations ii-ix are summarized in Table 4.5.

Table 4.4: Barriers level iteration i

S. No.	*Reachability Set*	*Antecedents Set*	*Intersection Set*	*Level*
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1	1	
2	2,4,5,6,7,8,9,10,11,12,13	1,2,3,10,13,14	2,10,13	
3	2,3,4,5,6,7,8,9,10,11,12,13,14	1,3,14	3,14	
4	4,5,6,8,12	1,2,3,4,6,7,9,10,11,12,13,14	4,6,12	
5	5,8	1,2,3,4,5,6,7,9,10,11,12,13,14	5	
6	4,5,6,8,12	1,2,3,4,6,7,9,10,11,12,13,14	4,6,12	
7	4,5,6,7,8,11,12	1,2,3,7,9,10,13,14	7	
8	8	1,2,3,4,5,6,7,8,9,10,11,12,13,14	8	I
9	4,5,6,7,8,9,11,12	1,2,3,9,10,13,14	9	
10	2,4,5,6,7,8,9,10,11,12,13	1,2,3,10,13,14	2,10,13	
11	4,5,6,8,11,12	1,2,3,7,9,10,11,13,14	11	
12	4,5,6,8,12	1,2,3,4,6,7,9,10,11,12,13,14	4,6,12	
13	2,4,5,6,7,8,9,10,11,12,13	1,2,3,10,13,14	2,10,13	
14	2,3,4,5,6,7,8,9,10,11,12,13,14	1,3,14	3,14	

Table 4.5: Barriers level iteration ii-ix

Iteration	*Barriers*	*Reachability Set*	*Antecedents Set*	*Intersection Set*	*Level*
ii	5	5	1,2,3,4,5,6,7,9,10,11,12,13,14	5	II
iii	4	4,6,12	1,2,3,4,6,7,9,10,11,12,13,14	4,6,12	III
iii	6	4,6,12	1,2,3,4,6,7,9,10,11,12,13,14	4,6,12	III
iii	12	4,6,12	1,2,3,4,6,7,9,10,11,12,13,14	4,6,12	III
iv	11	11	1,2,3,7,9,10,11,13,14	11	IV
v	7	7	1,2,3,7,9,10,13,14	7	V
vi	9	9	1,2,3,9,10,13,14	9	VI
vii	2	2,10,13	1,2,3,10,13,14	2,10,13	VII
vii	10	2,10,13	1,2,3,10,13,14	2,10,13	VII
vii	13	2,10,13	1,2,3,10,13,14	2,10,13	VII
viii	3	3,14	1,3,14	3,14	VIII
viii	14	3,14	1,3,14	3,14	VIII
ix	1	1	1	1	IX

4.4.4 Developing conical matrix

The conical matrix is generated by clubbing all barriers according to their level across the columns and rows of the final reachability matrix which is used for developing the final diagraph and later a structural model. For example, the barrier 8 is found at level I, 5 at level II, 4, 6, and 12 at level III. Similarly, all barriers are clubbed as per their level partition (see Table 4.5). Further, the dependence power and driving power of a barrier are determined by summing up the number of 1's in the columns and by summing up the number of 1's in the rows respectively. Subsequently, ranks are calculated by giving the highest rank to the barriers that have the maximum number of 1s in the rows and columns indicating driving power and dependence power. After rearranging, the conical matrix is obtained as shown in Table 4.6.

Table 4.6: Conical matrix

Barriers S. No.	*8*	*5*	*4*	*6*	*12*	*11*	*7*	*9*	*2*	*10*	*13*	*3*	*14*	*1*	*Driving Power*
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
4	1	1	1	1	1	0	0	0	0	0	0	0	0	0	5
6	1	1	1	1	1	0	0	0	0	0	0	0	0	0	5
12	1	1	1	1	1	0	0	0	0	0	0	0	0	0	5
11	1	1	1	1	1	1	0	0	0	0	0	0	0	0	6
7	1	1	1	1	1	1	1	0	0	0	0	0	0	0	7
9	1	1	1	1	1	1	1	1	0	0	0	0	0	0	8
2	1	1	1	1	1	1	1	1	1	1	1	0	0	0	11
10	1	1	1	1	1	1	1	1	1	1	1	0	0	0	11
13	1	1	1	1	1	1	1	1	1	1	1	0	0	0	11
3	1	1	1	1	1	1	1	1	1	1	1	1	1	0	13
14	1	1	1	1	1	1	1	1	1	1	1	1	1	0	13
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Dependence	14	13	12	12	12	9	8	7	6	6	6	3	3	1	

4.4.5 Development of digraph

Based on the conical form of reachability matrix, an initial digraph including transitivity links is generated by nodes and lines of the edges. Suppose there is a relationship between two barriers, then it is shown by an arrow from one barrier to another barrier. After confirming the hierarchy, an arrow is required to show the direction of the action. If barrier i acts on barrier j, an arrow will be used to point from i to j. Similarly, a graph is achieved after all the relationships (direct and indirect) are completed. Finally, the diagraph is developed by removing the indirect links as shown in Figure 4.3. The top level barrier is placed at the top of the diagraph and the next level barrier is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph.

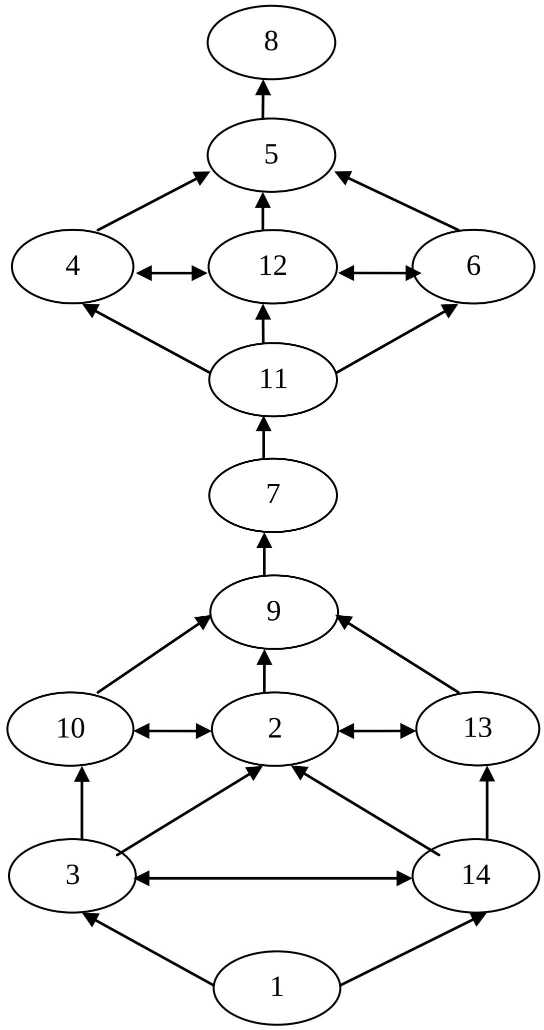

Figure 4.3: Levels of automotive SCPM barriers

4.4.6 Building the ISM-based model

In this section, the final digraph is transformed into an ISM model with barrier statements as presented in Figure 4.4. Figure 4.4 shows that a lack of awareness related to a SCPM system (Barrier 1) is the most crucial barrier for the Indian automotive firms as it comes at the bottom of the ISM hierarchy. Encroaching market competition and the uncertainty of demand (Barrier 8) appeared at the top which indicate it will influence the entire process of the SC. The Barrier 1 leads to the lack of top management's dedication (Barrier 3) towards implementing a PM system in automotive SC. Similarly, Barrier 3 leads to the destitute quality of human resources (Barrier 14). The destitute quality of human resources (Barrier 14) should be positioned before assigning inadequate strategic planning (Barrier 2), lack of funding or financial constraints (Barrier 13), and lack of support from government systems (Barrier 10) that would counter SCPM in the Indian firms.

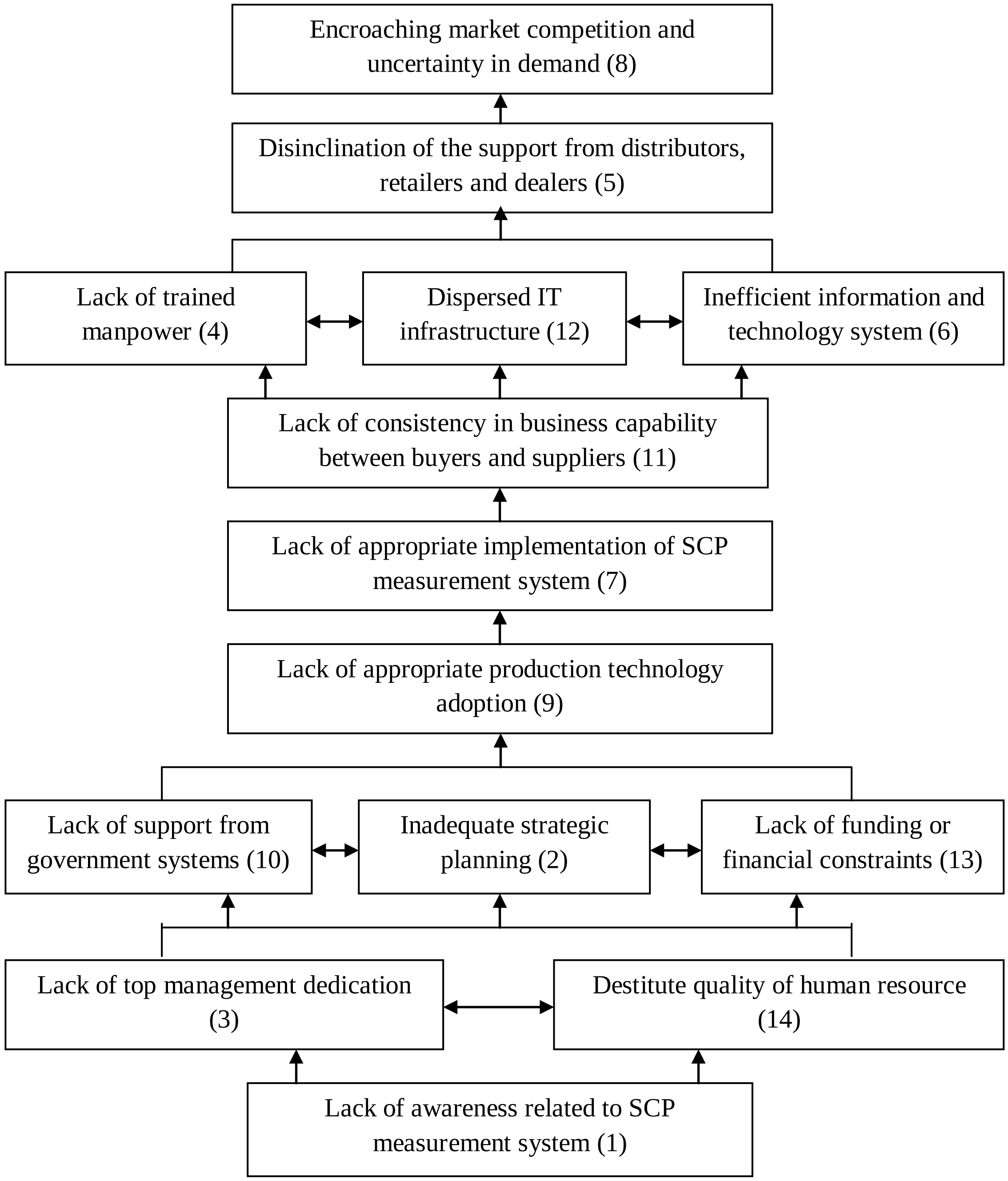

Figure 4.4: ISM-based model for automotive SCPM barriers

Inadequate strategic planning (Barrier 2), lack of support from government systems (Barrier 10), and the lack of funding or financial constraints (Barrier 13) are interrelated and lead to a lack of appropriate production technology adoption (Barrier 9). Barrier 9 leads to a lack of appropriate implementation of a SCP measurement system (Barrier 7) and the lack of consistency in business capability between buyers and supplier (Barrier 11). The Barrier 11 leads to a lack of trained manpower (Barrier 4), inefficient information and technology systems (Barrier 6) and a dispersed IT infrastructure (Barrier 12). The Barriers 4, 6 and 12 are interrelated and help in the disinclination of support from distributors, retailers and dealers (Barrier 5).

As the trained manpower and efficient information are crucial for SCPM system implementation and without the support of distributors and retailers it will be very difficult to achieve. Finally, Barrier 5 leads to encroaching market competition and the uncertainty of demand (Barrier 8). Therefore, all these barriers are crucial in the Indian automotive SC. Moreover, without the support of all the bottom side barriers, it would be difficult to fill the all gaps of SC process.

4.5 Integration of ISM and fuzzy MICMAC

The direct and indirect relationships between the barriers to implementation SCPM system across the Indian automotive SC were carried out by an ISM (Warfield, 1974) and fuzzy MICMAC (Duperrin and Godet, 1973). A direct relationship matrix is obtained by examining the direct relationships among the criterion in the ISM. The transitivity is ignored and the diagonal entries are converted into zero. Then a direct relationship matrix (DRM) is derived.

4.5.1 Development of fuzzy direct relationship matrix (FDRM)

Generally, MICMAC considers only binary types of relationships; therefore at this stage we have used the fuzzy set theory to increase the earlier sensitivity. With fuzzy MICMAC an additional input of possible interactions among the barriers is established. Similar to Qureshi *et al.* (2008), the possibility of interaction can be defined by a qualitative consideration on a 0 to 1 scale as shown in Table 4.7. The possibility of the numerical value of reachability is covered up on the direct relationship matrix (DRM) to obtain a fuzzy direct relationship matrix (FDRM). Further, the DRM is achieved by examining the direct relationship among the barriers in digraph, disregarding the transitivity, and making diagonal entries 0. DRM and FDRM are presented in Table 4.8 and Table 4.9 respectively.

Table 4.7: Fuzzy scale

Possibility of Reachability	No	Negligible	Low	Medium	High	Very High	Full
Value	0	0.1	0.3	0.5	0.7	0.9	1.0

4.5.2 Convergence of fuzzy direct relationship matrix

FDRM is used to start the procedure of finding the fuzzy indirect relationship between the barriers. The matrix is multiplied or reproduced repeatedly up to a power until the hierarchies of the driving and dependence power are stabilized. This multiplication process follows the principle of fuzzy matrix multiplication. It is known that the fuzzy matrix multiplication is basically a generalization of the Boolean matrix multiplication. According to the fuzzy set theory, when two fuzzy matrices are multiplied, the product matrix will also be a fuzzy matrix. Multiplication follows the rule given below: the product of fuzzy set A and B is fuzzy set C.

$C = A, B = \text{maxk}[\min(a_{ik}, b_{kj})]$ where, $A = (a_{ik})$ and $B = (b_{kj})$ are two fuzzy matrices

4.5.3 Stabilization of fuzzy matrix

As discussed in the previous section, the FDRM process and matrix multiplication is used to stabilize the matrix as shown in Table 4.10. The dependence power, driving power, and ranks are determined as discussed earlier section. The ranks of the driving power of the criterion decide the hierarchy of criterion in the system. The purpose of this classification of the barriers is to analyze the driving and dependence power of barriers that influence SCP.

Table 4.8: Direct relationship matrix (DRM)

S. No.	*Barriers*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	Lack of awareness related to SCP measurement system	0	1	1	1	1	1	1	1	1	0	1	1	1	1
2	Inadequate strategic planning	0	0	0	1	1	1	0	1	1	1	1	1	1	0
3	Lack of top management dedication	0	1	0	1	1	1	0	0	1	1	1	1	1	1
4	Lack of trained manpower	0	0	0	0	1	1	0	0	0	0	0	1	0	0
5	Disinclination of the support from distributors, retailers and dealers	0	0	0	0	0	0	0	1	0	0	0	0	0	0
6	Inefficient information and technology system	0	0	0	0	1	0	0	1	0	0	0	1	0	0
7	Lack of appropriate implementation of SCP measurement system	0	0	0	1	1	1	0	1	0	0	1	1	0	0
8	Encroaching market competition and uncertainty in demand	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Lack of appropriate production technology adoption	0	0	0	1	1	1	1	1	0	0	1	0	0	0
10	Lack of support from government systems	0	0	0	0	1	1	1	0	1	0	1	1	1	0
11	Lack of consistency in business capability between buyers and suppliers	0	0	0	1	1	1	0	1	0	0	0	1	0	0
12	Dispersed IT infrastructure	0	0	0	1	1	1	0	0	0	0	0	0	0	0
13	Lack of funding or financial constraints	0	1	0	1	1	1	1	0	1	0	1	1	0	0
14	Destitute quality of human resource	0	1	1	1	1	1	1	1	1	0	1	1	1	0

Table 4.9: Fuzzy direct relationship matrix (FDRM)

Barriers S. No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*Sum*
1	0	0.7	0.5	0.3	0.3	0.3	0.5	0.1	0.5	0	0.3	0.3	0.5	0.5	4.8
2	0	0	0	0.5	0.5	0.5	0	0.3	0.7	0.5	0.7	0.5	0.9	0	5.1
3	0	0.7	0	0.5	0.3	0.5	0	0	0.5	0.3	0.5	0.5	0.7	0.5	5
4	0	0	0	0	0.7	0.5	0	0	0	0	0	0.5	0	0	1.7
5	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0.5
6	0	0	0	0	0.7	0	0	0.3	0	0	0	0.5	0	0	1.5
7	0	0	0	0.5	0.7	0.5	0	0.5	0	0	0.7	0.5	0	0	3.4
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0.5	0.7	0.7	0.9	0.7	0	0	0.7	0	0	0	4.2
10	0	0	0	0	0.3	0.3	0.7	0	0.9	0	0.7	0.5	0.5	0	3.9
11	0	0	0	0.5	0.7	0.5	0	0.5	0	0	0	0.5	0	0	2.7
12	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	1.5
13	0	0.7	0	0.5	0.5	0.7	0.9	0	0.7	0	0.3	0.7	0	0	5
14	0	0.5	0.3	0.3	0.5	0.5	0.9	0.3	0.7	0	0.5	0.3	0.3	0	5.1
Sum	0	2.6	0.8	4.1	6.4	5.5	3.9	3.2	4	0.8	4.4	4.8	2.9	1	

Table 4.10: Fuzzy stabilized matrix

Barriers S. No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*Sum*	*Rank*
1	0	0.7	0.3	0.5	0.7	0.7	0.7	0.7	0.7	0.5	0.7	0.7	0.5	0.3	7.7	1
2	0	0.5	0	0.5	0.7	0.7	0.7	0.7	0.7	0.5	0.7	0.5	0.7	0	6.9	5
3	0	0.7	0	0.5	0.7	0.7	0.7	0.7	0.7	0.5	0.7	0.7	0.7	0.3	7.6	2
4	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0.5	0	0	2.5	7
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
6	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0.5	0	0	2.5	7
7	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0.5	0	0	2.5	7
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
9	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0.5	0	0	2.5	7
10	0	0.5	0	0.5	0.7	0.7	0.8	0.7	0.8	0.8	0.7	0.5	0.5	0	7.2	3
11	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0.5	0	0	2.5	7
12	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0.5	0	0	2.5	7
13	0	0.7	0	0.5	0.7	0.7	0.7	0.7	0.7	0.5	0.7	0.7	0.5	0	7.1	4
14	0	0.5	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	5.8	6
Sum	0	3.6	0.6	6	7	7	4.1	7	4.1	3.3	4	6.6	3.4	0.6		
Rank	13	5	14	3	1	1	5	1	5	13	5	4	10	10		

4.5.4 MICMAC analysis

Duperrin and Godet (1973) developed MICMAC method to study diffusion of impacts through reaction paths and loops for developing a hierarchy of the variables and can be used to identify and analyze the barriers in a complicated system (Warfield, 1990). MICMAC theory is based on the multiplication properties of matrices (Raj *et al.*, 2008) and its purpose is to analyze the driving power and the dependence of the variables or barriers (Mandal and Deshmukh, 1994; Faisal *et al.*, 2006). In MICMAC analysis, all the barriers are clustered into four categories as presented in Figure 4.5.

The first cluster comprises of the barriers that have a weak driving power and weak dependence. They are called autonomous barriers as these barriers are relatively disconnected from the system and have only a few links that may be strong. A second cluster describes dependent the barriers that have a weak driving power but strong dependence. The third cluster includes barriers that have a strong driving power and dependence. The fourth cluster comprises the barriers that have strong driving power and weak dependence, which are called the driver barriers. It is observed that if the barrier having a strong driving power (cluster IV), called a key barrier, will obviously fall into the cluster of the driver barriers or linkage barriers. Table 4.6 indicates the driving power and dependence power of each barrier. Finally, these driving power and dependence power of each barrier can be placed into four clusters as shown in Figure 4.5.

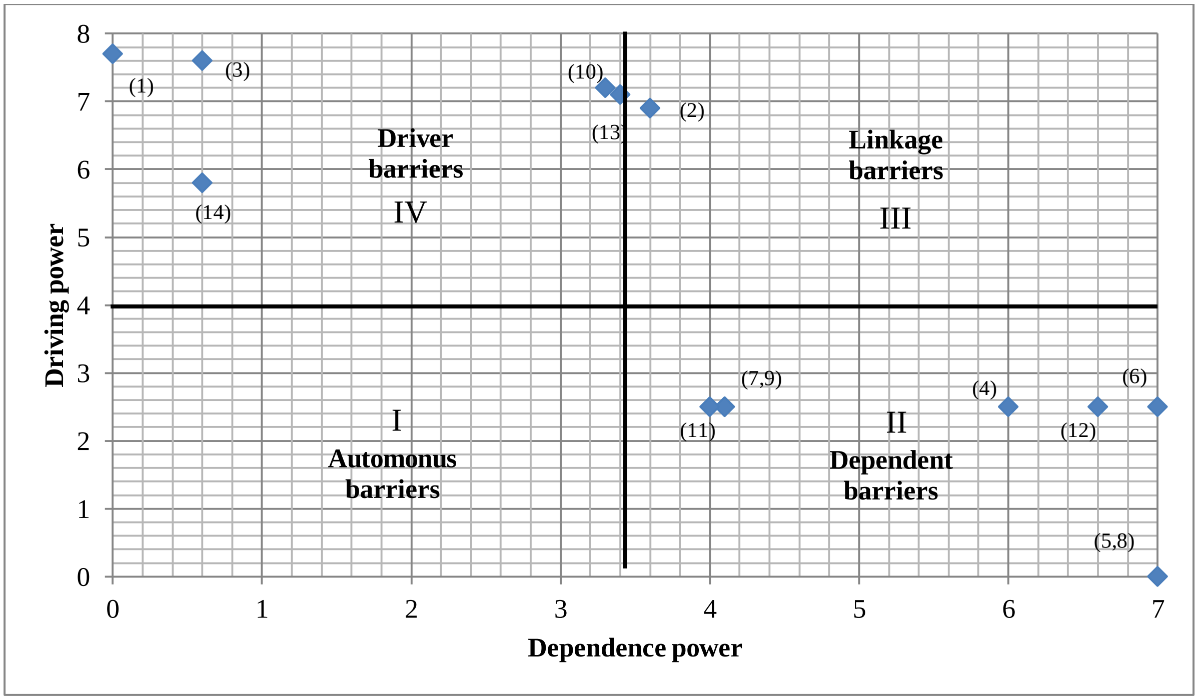

Figure 4.5: Driving power and dependence power diagram

4.5.5 Fuzzy MICMAC analysis

Fuzzy MICMAC derived from the FDRM can be of a great help as the significance of a criterion is measured by its direct interrelationships and more by many indirect interrelationships (Saxena *et al.*, 1992; Qureshi *et al.*, 2008). The indirect relationships between the barriers have an impact on selection method through the influence of the interactions in the form of chains and reaction loops known as feedbacks. The Fuzzy set theory is applied for each criterion to the traditional MICMAC. The fuzzy MICMAC facilitates in the critical investigation of each criterion. All criteria are clustered into four categories in a MICMAC analysis as discussed earlier and shown in Figure 4.5.

4.6 Conclusion and managerial implications

This chapter presents the barriers that are essential and pose considerable challenges for the policy makers and managers to measure SCP in the Indian automotive industry. First, fourteen barriers are identified based on literature review and experts' opinion from the Indian automotive firms. Second, brainstorming sessions were conducted with sixteen experts to develop a relationship matrix as the first step towards developing an ISM-based model. The barriers identified in this study helps to measure the SCP and that is helpful for companies to become more successful and efficient. The fuzzy MICMAC was utilized to driving power and dependency power (see Figure 4.5) of four clusters with the help of fuzzy numbers. Figure 4.5 provides valuable suggestions to the top managers of automotive firms about impact of the identified barriers. The results show that the lack of awareness related to SCP measurement system (Barrier 1) is one of the major barriers, and indications a higher driving power at the bottom level of the model. Therefore, the top management should put more focus on this barrier to build effective and efficient SC.

There are no autonomous barriers for this study and all considered barriers influence the SCP in the Indian automotive organizations (see Figure 4.5). It is also observed that the encroaching market competition and uncertainty in demand (Barrier 8), disinclination of the support from distributors, retailers and dealers (Barrier 5), lack of trained manpower (Barrier 4), dispersed IT infrastructure (Barrier 12), inefficient information and technology system (Barrier 6), lack of consistency in business capability between buyers and suppliers (Barrier 11), lack of appropriate implementation of SCP measurement system (Barrier 7), and lack of appropriate production technology adoption (Barrier 9) are the weak driving barriers. However, these barriers have a strong dependence on other barriers such as lack of support from government systems (Barrier 10), lack of funding or financial constraints (Barrier 13), lack of top management dedication (Barrier 3), destitute quality of human resource (Barrier 14), and lack of awareness related to SCP measurement systems (Barrier 1).

Figure 4.5 shows that there is only one linkage barrier i.e., inadequate strategic planning (Barrier 2) which connects the driving barriers with dependent barriers. The linkage barriers are derived from the absolute driving barrier and results in an absolute dependent barrier. Only five barriers have a strong driving power and are less dependent on others. Therefore, these are the root barriers and a firms' top management must give more attention to these barriers in order to become successful. These findings may help the top management in identifying the barriers that affect SCP improvement. In this chapter specifically developed a model to explore the barriers of SCPM in the Indian automotive firm. However, it is generalized in nature, so it can be utilized in other business industries as well.

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CHAPTER 5
Multi-attribute Comparison of the Indian Automotive Suppliers

Preview

This chapter proposed an integrated fuzzy AHP model to improve supply chain performance by means of right supplier selection under multiple criteria. An initial model has been developed using literature review and experts' opinion to compare the various attributes/criteria and sub-attributes/sub-criteria of supply chain performance. A best supplier is selected from the cohort of potential suppliers by ranking the suppliers using fuzzy AHP methodology on the basis of attributes and sub-attributes of supply chain performance.

5.1 Introduction

In current business environment, suppliers are the hearts of any business performance, as suppliers help in reducing product cost, manufacturing time, lead times, and quality improvement (Kumar *et al.*, 2006; Meena and Sarmah, 2012). The products or materials supplied from the suppliers play an essential role in improving the competitiveness of any supply chains (SC) (Park *et al.*, 2010). Supplier selection is an important process for improving supply chain performance (SCP) and generally done based on different performance criteria such as product cost, quality, delivery times, etc. (Ha and Krishnan, 2008; Viswanadham and Samvedi, 2013; Kumar *et al.*, 2006; Yang *et al.*, 2008; Rao, 2002; Hutchins and Sutherland, 2008). According to Ageron *et al.* (2012), a firm needs to measure SCP and put targets for performance improvement before its suppliers. It is very difficult for firms to produce low-cost and high-quality products without satisfactory suppliers. A good supplier base helps a company to achieve greater innovation through improved product design and increased flexibility (Meena *et al.*, 2011; Sarkar and Mohapatra, 2006). Meena and Sharma (2012) mentioned that suppliers are the true partners for value creation in SC and building a long-term relationship with suppliers is the need of the hour for the buyers. Therefore, selection of an appropriate supplier is essential for better procurement process and cost reduction (Peters *et al.*, 2011; Ciliberti *et al.*, 2008; Blowfield, 2005). Weber *et al.* (1991) revealed that selection of wrong supplier may affect operational and financial performance of organization. Organizations have learnt that single criterion consideration is in sufficient for supplier selection.

Nowadays, suppliers need to be evaluated on more than one criterion. Many authors have advocated that multiple criteria must be considered for supplier selection and supplier performance evaluation (Dickson, 1966; Dempsey, 1978; Weber *et al.,* 1991; Kahraman *et al.,* 2003; Sarkar and Mohapatra, 2006; Bai and Sarkis, 2010). This chapter focuses on supplier selection and supplier evaluation based on the performance criteria using Multiple Criteria Decision Making (MCDM) techniques in the Indian automotive industry. SCP attributes and sub-attributes are identified (see Chapter 2 and Chapter 3) with the help of experts' opinion.

Analytic hierarchy process (AHP) method is easy to understand and can effectively handle both quantitative and qualitative data. It usually captures the expert's knowledge; nevertheless, the conventional AHP can not reflect the human thinking style. Therefore, fuzzy AHP was utilized here to see the hierarchical problems. In practice, the available information in a MCDM process is usually vague or fuzzy and the criteria are not necessarily independent. Zadeh (1965) introduced fuzzy sets concept to improve the modelling of vague parameters. Kahraman *et al.* (2003) used MCDM techniques to select the best supplier for a manufacturing organization in Turkey. Badri (2001) applied AHP method to find the weight of five sets of quality performance measures. Ghodsypour and O'Brien (1998) used AHP and mathematical programming to determine the best order quantity allocation while considering qualitative criteria into the analysis. In past years, various methods have been used for supplier selection such as linear weighting methods, mathematical programming models, and statistical methods. Recently, Kumar *et al.* (2006) used a fuzzy approach for supplier selection.

Many authors have used AHP, fuzzy AHP, ANP, DEA, and fuzzy TOPSIS methods separately or combined for supplier evaluation and supplier selection (Morlacchi, 1999; Weber *et al.*, 2000; Bevilacqua and Petroni, 2002; Mikhailov, 2002; Cebeci and Kahraman, 2002; Simpson *et al.*, 2003; Dulmin and Mininno, 2003; Bello, 2003; Wang *et al.*, 2004; Kumar *et al.*, 2004; Shyur and Shih, 2006; Kuo *et al.*, 2010; Awasthi *et al.* (2010). De Boer *et al.* (2001) provided a comprehensive literature review on supplier selection. Yang *et al.* (2008) proposed integrated fuzzy MCDM technique for supplier selection problem and used fuzzy AHP method to compute the relative weights for each attribute and sub-attribute. Zeydan *et al.* (2011) introduced and proposed fuzzy AHP and fuzzy TOPSIS methodologies for supplier selection and performance evaluation. Shaw *et al.* (2012) used fuzzy AHP for supplier selection in low carbon emission SCs.

In this chapter, fuzzy AHP method is used for supplier selection problem in the Indian automotive industry. Thus, a decision maker can choose better supplier in the form of their performance of attributes (i.e., plan, source, manufacturing, delivery, and customer service) and sub-attributes. Moreover, this study is essential because buyers' performance increasingly rotate on the capabilities of its suppliers.

The organization of this chapter is as follows. Section 5.2 discusses the attributes and sub-attributes of the SCP measurement. Section 5.3 describes fuzzy AHP based research methodology. A case illustration of an Indian automotive company and multi-attribute comparison of automotive suppliers are discussed in Section 5.4. Conclusion and managerial implications are presented in Section 5.5.

5.2 Identification of attributes and sub-attributes

In this chapter, attributes and sub-attributes are identified from the literature and experts' opinion as discussed in Chapter 2. Attributes of SCPM and their definitions are presented in Table 2.3 (see Chapter 2). Table 2.4 (see Chapter 2) demonstrates the five attributes (i.e., plan, source, manufacturing, delivery, and customer service) and twenty sub-attributes (i.e., order entry method, order lead-time, customer order path, supplier selection, purchase order cycle time, buyer-supplier relationship, mutual assistance in solving problems, effectiveness of master production schedule, product cost, quality, flexibility, range of product and services, flexibility of delivery systems to meet particular customer needs, effectiveness of delivery invoice methods, on time delivery of goods, flexibility to meet particular customer needs, post transaction measures of customer service, and customer query time) with their references. Table 2.6 (see Chapter 2) presents supplier evaluation/supplier selection studies which have used fuzzy AHP approach.

5.3 Research methodology

We have used fuzzy AHP technique to select the best supplier for an Indian automotive industry. A brainstorming session was organized and discussed on the attributes and sub-attributes of SCP measurement. Experts' gave preference to the attributes and sub-attributes in a comparison matrix. Fuzzy AHP with fuzzy set theory, computational procedure, and supplier selection model are discussed in the following sub-sections. A case on Indian automotive company was also discussed in further section 5.4.

5.3.1 Fuzzy analytic hierarchy process (fuzzy AHP)

Fuzzy set theory helps in dealing with the vagueness and fuzziness of uncertain environments (Zadeh, 1965). The fuzzy set theory can be used to remove the vagueness in qualitative and quantitative data (Lee *et al.*, 2005; Dareli *et al.*, 2007; Baykasoglu and Gocken, 2012). In analytic hierarchy process (AHP), pair wise comparison is done but its appropriateness can be questioned in real life decisions (Shaw *et al.*, 2012). To solve this problem, decision models should incorporate a fuzzy theory (Lee, 2009; Yu, 2002). A selection of alternatives in fuzzy AHP is used by the fuzzy set theory and conventional AHP (Bozbura *et al.*, 2007). Fuzzy AHP is frequently used in the research for decision making, and various methods have been proposed for computing fuzziness (Buckley, 1985; Chang, 1996; Chen, 1996; Lee *et al.*, 2005; Lee *et al.*, 2008; Lee, 2009). These methods have their own advantages and disadvantages.

Considering the simplicity of calculations and itsadvantages over other methods, Chang (1996) used the extent analysis method for fuzzy AHP. This approach deals with the uncertainty in decision making and is more robust in nature (Chan and Kumar, 2007). It uses a triangular fuzzy number for a pair wise comparison of different decision variables. Furthermore, extent analysis is used to find the synthetic value from the pair wise comparison.

A triangular fuzzy number M can be represented by (a, b, c) with its membership function as shown in Figure 5.1 (Lee *et al.*, 2009a; Lee *et al.*, 2009b; Lee *et al.*, 2005; Wong *et al.*, 2012).

$$\mu_m(x) = \begin{cases} \frac{x-a}{b-a} & (a \leq x \leq b) \\ \frac{c-x}{c-b} & (b \leq x \leq c) \\ 0 & otherwise \end{cases} \quad (1)$$

with $-\infty < a \leq b \leq c \leq \infty$.

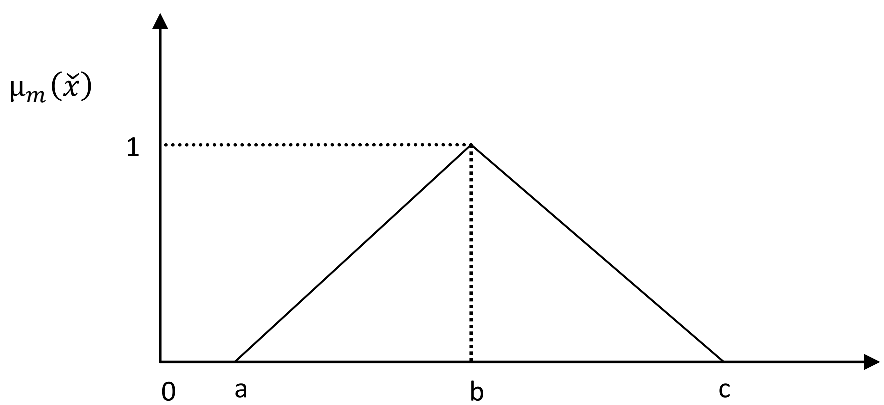

Figure 5.1: Triangular fuzzy number

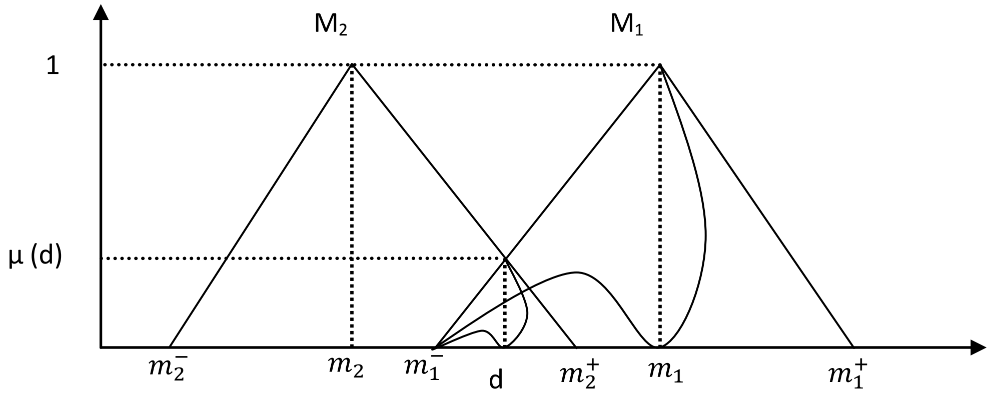

Figure 5.2: Two triangular fuzzy numbers M_1 and M_2 (Lee, 2009).

The strongest grade of membership is the parameter b that is, f_M (b) = 1, while a and c are the lower and upper bounds. Two triangular fuzzy numbers M_1 (m_1^-, m_1, m_1^+) and M_2 (m_2^-, m_2, m_2^+) are shown in Figure 5.2.

Where, $m_1^- \geq m_2^-, \quad m_1 \geq m_2, \quad m_1^+ \geq m_2^+)$ (2)

The degree of possibility can be represented as

V ($M_1 \geq M_2$) = 1 (3)

Otherwise, the ordinate of the highest intersection point is calculated as (Chang, 1996; Zhu *et al.*, 1999; Lee, 2009; Shaw *et al.*, 2012).

V ($M_1 \geq M_2$) = hgt ($M_1 \cap M_2$) = µ (d) = $\frac{m_1^- - m_-^+}{(m_2 - m_2^-) - (m_1 - m_1^-)}$ (4)

Equation (5) to (11) can be used for the calculation of the fuzzy synthetic extent value (Chang, 1996; Zhu *et al.*, 1999; Lee, 2009; Shaw *et al.*, 2012).

$$\text{Fi} = \sum_{j=i}^{m} M_{gi}^{j} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right)^{-1}, \qquad i = 1,2, \ldots \ldots . . n \qquad (5)$$

$$\sum_{j=i}^{m} M_{gi}^{j} = \left(\sum_{j=i}^{m} M_{ij}^{-}, \sum_{j=i}^{m} M_{ij}, \sum_{j=i}^{m} M_{ij}^{+} \right) \qquad i = 1,2, \ldots \ldots . . n \qquad (6)$$

$$\left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right)^{-1} = \left[\frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}^{+}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}^{-}} \right] \qquad (7)$$

A convex fuzzy number can be defined as,

$V(F \geq F_1, F_2 \ldots F_K) = \min V(F \geq F_i), \quad i = 1, 2, \ldots\ldots k$ (8)

$d(F_i) = \min V(F \geq F_k) = W_i' \; k = 1, 2, \ldots\ldots, n \text{ and } k \neq i$ (9)

Based on the above procedure, the weights, W_i' of the factors are

$$W' = (W_1', W_2', \ldots\ldots, W_n')^T \tag{10}$$

After normalization, the priority weights are as follows

$$W' = (W_1, W_2, \ldots\ldots, W_n)^T \tag{11}$$

5.3.2 Computational procedure

Here, Fuzzy AHP is used to determine the relative weights of the supplier selection criteria. These weights are used in the weighted additive model for multiplying with the respective membership function to obtain the crisp equation. The computational procedure of the model is as follows:

Step 1: The supplier selection criteria are identified to measure SCP.

Step 2: A nine-point scale questionnaire is developed for pair-wise comparison by the experts. Experts are included from the operations/manufacturing department of the companies.

Step 3: The response of the experts is used to calculate fuzzy importance weight. Experts' opinions are combined to obtain a triangular fuzzy number Ď (Lee, 2009). The characteristic function of the fuzzy number is shown in Table 5.1.

Ď = (h^-, h, h^+)

Where,

$$h^- = \left(\prod_{t=1}^{s} l_t\right)^{\frac{1}{s}}, \qquad \forall t = 1,2 \ldots s.$$

$$h = \left(\prod_{t=1}^{s} m_t\right)^{\frac{1}{s}}, \qquad \forall t = 1,2 \ldots s.$$

$$h^+ = \left(\prod_{t=1}^{s} n_t\right)^{\frac{1}{s}}, \qquad \forall t = 1,2 \ldots s.$$

l_t, m_t, u_t are the lower, middle, and upper limits of fuzzy response from expert t.

Step 4: Fuzzy extent analysis method is used to obtaining the crisp relative priority of attributes, sub-attributes, and alternatives.

Table 5.1: Fuzzy scale

Fuzzy Number	Membership Function
$\tilde{1}$	(1,1,2)
$\tilde{x}$	(x-1, x, x+1) for x= 2,3,4,5,6,7,8
$\tilde{9}$	(8,9,9)
$1/\breve{1}$	$(2^{-1}, 1^{-1}, 1^{-1})$
$1/\breve{x}$	$((x+1)^{-1}, x^{-1}, (x-1)^{-1})$ for x= 2,3,4,5,6,7,8
$1/\breve{9}$	$(9^{-1}, 8^{-1}, 8^{-1})$

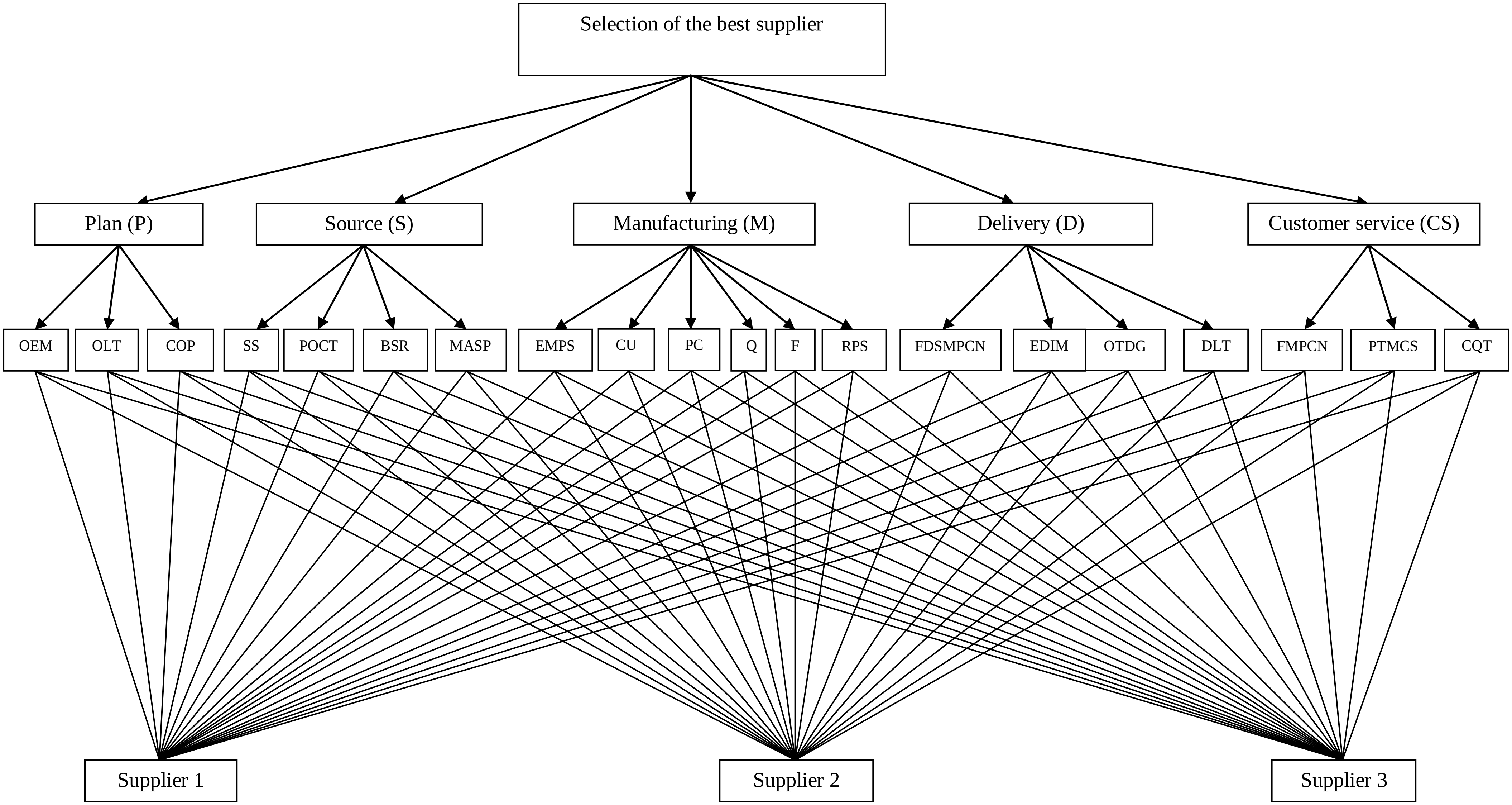

Figure 5.3: The hierarchy of the problem

5.4 A case illustration

To illustrate the effectiveness of the model a case study was conducted at the corporate office of an automotive company XYZ based in IMT Manesar, Gurgaon, India. The company has several manufacturing plants across the India and has many domestic and well as overseas customers based in Japan, USA, Italy, China etc. of two wheelers, four wheelers, and commercial vehicles. The company produces various products such as auto fuel cocks, oil pumps, speed sensors, fuel level sensors, power sockets, brake light switches, auto fare meter, gear, pistons, and temperature sensors etc. The company procures items from various suppliers in semi-finished and finished forms.

Due to increased demand of domestic as well as International customers, the company XYZ is having more pressure and responsibilities in terms of product quality, flexibility, product delivery, and tailored customers' requirement. To fulfil the customers' need, company is maintaining better relationship with its customers as well as suppliers. Moreover, the company is focusing on improving the overall performance of its supply chain. The company is facing a challenge of how to select the best supplier(s) from the large cohort of potential suppliers. Although, company has good relationship with their suppliers as well as customers, however, it still wants to improve it to a further level. The relationship between the two parties depends upon the product quality, flexibility, delivery, and many more attributes of the suppliers. Consequently, for better supplier selection, management has invited experts from the production, marketing, quality, research, and SC departments for their involvement in supplier selection. There were only six experts from the above given departments related.

A brainstorming session was conducted to select the best supplier for SCP improvement. Management gave preference to attributes (plan, source, manufacturing, delivery, and customer service) and their sub-attributes. Experts pointed out that these attributes and sub-attributes are the key points to evaluate suppliers' performance. Finally, the committee decided and confirmed the above discussed five attributes and twenty sub-attributes to solve the problem. Three suppliers (i.e., supplier 1, supplier 2, and supplier 3) of company XYZ were selected to illustrate the model. In brainstorming session, experts' were asked to prioritize the attributes and sub-attributes using fuzzy AHP technique. The fuzzy pair-wise comparison matrix with respect to the goal is shown in Table 5.2. Similarly, other pair-wise comparison matrices are finalized with respect to the attributes and sub-attributes with the help of experts' opinion.

5.4.1 Multi-attribute comparison of three automotive suppliers

The Indian automotive industries can improve their SCP by selecting better suppliers. The goal is to select the best supplier from cohort of three suppliers. The decision-making group consists of six experts from the case company. The hierarchy of attributes and sub-attributes is shown in Figure 5.3. The fuzzy evaluation matrix for the considered goal is shown in Table 5.2 and the questionnaire of fuzzy comparison matrices are presented in Appendix C. The decision-making group compared the sub-attributes with respect to the main-attributes. First, they were asked to compare the sub-attributes of plan. Table 5.3 gives the fuzzy comparison data of the sub-attributes of plan. The other matrices of pair-wise comparisons and the weight vectors of each matrix are given in Tables 5.4 to Table 5.7 respectively. The six experts compared the suppliers with respect to the sub-attributes which are shown in Table 5.9 to Table 5.28.

Table 5.2: The fuzzy evaluation matrix with respect to the goal

	P	S	M	D	CS
P	(1,1,1)	(1,1,2)	(1,1,2)	(1.91,2.62,3.70)	(1.78,2.50,3.56)
S	(0.5,1,1)	(1,1,1)	(0.31,0.48,0.63)	(1,1,2)	(0.31,0.48,0.63)
M	(0.5,1,1)	(1.59,2.09,3.17)	(1,1,1)	(1.12,1.20,1.24)	(1.26,1.44,2.52)
D	(0.27,0.38,0.52)	(0.5,1,1)	(0.45,0.83,0.89)	(1,1,1)	(0.27,0.40,0.49)
CS	(0.28,0.40,0.56)	(1.59,2.09,3.17)	(0.4,0.69,0.79)	(2.05,2.50,3.68)	(1,1,1)

From Table 5.2,

S_P = (6.69, 8.12, 12.26)*(1/40.58, 1/29.11, 1/23.09) = (0.16, 0.28, 0.53)

S_S = (3.13, 3.96, 5.26)*(1/40.58, 1/29.11, 1/23.09) = (0.08, 0.14, 0.23)

S_M = (5.47, 6.74, 9.94)*(1/40.58, 1/29.11, 1/23.09) = (0.13, 0.23, 0.43)

S_D = (2.49, 3.61, 3.90)*(1/40.58, 1/29.11, 1/23.09) = (0.06, 0.12, 0.17)

S_{CS} = (5.31, 6.68, 9.21)*(1/40.58, 1/29.11, 1/23.09) = (0.13, 0.23, 0.40)

Using these vectors,

$V(S_P \geq S_S) = 1.00$, $V(S_P \geq S_M) = 1.00$, $V(S_P \geq S_D) = 1.00$, $V(S_P \geq S_{CS}) = 1.00$

$V(S_S \geq S_M) = 0.526$, $V(S_S \geq S_D) = 1.00$, $V(S_S \geq S_{CS}) = 0.526$, $V(S_S \geq S_P) = 0.33$

$V(S_M \geq S_D) = 1.00$, $V(S_M \geq S_{CS}) = 1.00$, $V(S_M \geq S_P) = 0.843$, $V(S_M \geq S_S) = 1.00$

$V(S_D \geq S_{CS}) = 0.266$, $V(S_D \geq S_P) = 0.058$, $V(S_D \geq S_S) = 0.818$, $V(S_D \geq S_M) = 0.266$

$V(S_{CS} \geq S_P) = 0.827$, $V(S_{CS} \geq S_S) = 1.00$, $V(S_{CS} \geq S_M) = 1.00$, $V(S_{CS} \geq S_D) = 1.00$

The weight vectors are calculated as follows:

$d(S_P) = \text{Min } V(S_P \geq S_S\ S_M\ S_D\ S_{CS}) = \text{Min}(1, 1, 1, 1) = 1$

$d(S_S) = \text{Min } V(S_S \geq S_M\ S_D\ S_{CS}\ S_P) = \text{Min}(0.526, 1, 0.526, 0.333) = 0.333$

$d(S_M) = \text{Min } V(S_M \geq S_D\ S_{CS}\ S_P\ S_S) = \text{Min}(1, 1, 0.843, 1) = 0.843$

$d(S_D) = \text{Min } V(S_D \geq S_{CS}\ S_P\ S_S\ S_M) = \text{Min}(0.266, 0.058, 0.818, 0.266) = 0.058$

$d(S_{CS}) = \text{Min } V(S_{CS} \geq S_P\ S_S\ S_M\ S_D) = \text{Min}(0.827, 1, 1, 1) = 0.827$

Thus, the weight vector from Table 5.2 is calculated as W_G

$W_G = (d(S_P)\ d(S_S)\ d(S_M)\ d(S_D)\ d(S_{CS}))^T$

$W_G = (1, 0.333, 0.843, 0.058, 0.827)^T$

$= (0.33, 0.11, 0.28, 0.02, 0.27)$

Table 5.3: Evaluation of the sub-attributes with respect to plan

	OEM	OLT	COP
OEM	(1,1,1)	(0.24,0.33,0.44)	(0.30,0.46,0.59)
OLT	(0.34,0.55,0.66)	(1,1,1)	(0.34,0.55,0.66)
COP	(0.71,1.20,1.41)	(0.40,0.69,0.79)	(1,1,1)

The weight vector from Table 5.3 is calculated as $W_P = (0.19, 0.29, 0.52)$.

Table 5.4: Evaluation of the sub-attributes with respect to source

	SS	POCT	BSR	MASP
SS	(1,1,1)	(1.12,1.35,2.40)	(0.40,0.69,0.79)	(1.26,1.62,2.70)
POCT	(0.42,0.74,0.89)	(1,1,1)	(0.29,0.44,0.55)	(0.40,0.69,0.79)
BSR	(1.26,1.45,2.52)	(1.82,2.30,3.42)	(1,1,1)	(1.26,1.44,2.52)
MASP	(0.37,0.62,0.79)	(1.26,1.45,2.52)	(0.40,0.69,0.79)	(1,1,1)

The weight vector from Table 5.4 is calculated as $W_S = (0.33, 0.02, 0.43, 0.22)$.

Table 5.5: Evaluation of the sub-attributes with respect to manufacturing

	EMPS	CU	PC	Q	F	RPS
EMPS	(1,1,1)	(0.28,0.42,0.52)	(0.25,0.35,0.47)	(0.40,0.69,0.79)	(1.41,1.73,2.83)	(0.25,0.37,0.44)
PC	(1.91,2.38,3.55)	(1,1,1)	(1.41,1.73,2.83)	(0.35,0.57,0.71)	(1.41,1.73,2.52)	(1.41,1.73,2.83)
CU	(2.14,2.87,3.98)	(0.35,0.58,0.71)	(1,1,1)	(0.35,0.57,0.71)	(1.59,2.08,3.17)	(1.26,1.44,2.52)
Q	(1.26,1.45,2.52)	(1.41,1.74,2.83)	(1.41,1.74,2.83)	(1,1,1)	(1.26,1.44,2.52)	(1.41,1.73,2.83)
F	(0.35,0.58,0.71)	(0.40,0.58,0.71)	(0.31,0.48,0.63)	(0.40,0.69,0.79)	(1,1,1)	(0.30,0.46,0.59)
RPS	(2.30,2.71,3.97)	(0.35,0.58,0.71)	(0.40,0.69,0.79)	(0.35,0.58,0.71)	(1.70,2.19,3.30)	(1,1,1)

The weight vector from Table 5.5 is calculated as W_M = (0.11, 0.25, 0.25, 0.25, 0.02, 0.12).

Table 5.6: Evaluation of the sub-attributes with respect to delivery

	FDSMPCN	EDIM	OTDG	DLT
FDSTMPCN	(1,1,1)	(1.12,1.20,2.24)	(0.33,0.52,0.62)	(1.26,1.44,2.52)
EDIM	(0.45,0.83,0.89)	(1,1,1)	(0.38,0.66,0.74)	(0.31,0.48,0.63)
OTDG	(1.62,1.91,3.05)	(1.35,1.52,2.62)	(1,1,1)	(1.26,1.62,2.70)
DLT	(0.40,0.69,0.79)	(1.59,2.09,3.17)	(0.37,0.62,0.79)	(1,1,1)

The weight vector from Table 5.6 is calculated as W_D = (0.28, 0.04, 0.40, 0.27).

Table 5.7: Evaluation of the sub-attributes with respect to customer service

	FMPCN	PTMCS	CQT
FMPCN	(1,1,1)	(1.26,1.44,2.52)	(1.59,2.08,3.17)
PTMCS	(0.40,0.69,0.79)	(1,1,1)	(0.30,0.46,0.59)
CQT	(0.31,0.48,0.63)	(1.70,2.19,3.30)	(1,1,1)

The weight vector from Table 5.7 is calculated as W_{CS} = (0.55, 0.02, 0.43).

Table 5.8: Relative priorities of control attributes and sub-attributes

Attributes	Weight	Sub-attributes	Weight	Integrated Priority	Rank
Plan (P)	0.33	OEM	0.1907	0.0629	6
		OLT	0.2938	0.0970	4
		COP	0.5155	0.1701	1
Source (S)	0.11	SS	0.3262	0.0359	8
		POCT	0.0215	0.0024	17
		BSR	0.4292	0.0472	7
		MASP	0.2232	0.0245	11
Manufacturing (M)	0.28	EMPS	0.1135	0.0318	10
		CU	0.2462	0.0689	5
		PC	0.2462	0.0689	5
		Q	0.2462	0.0689	5
		F	0.0246	0.0069	13
		RPS	0.1231	0.0345	9
Delivery (D)	0.02	FDSMPCN	0.2808	0.0056	15
		EDIM	0.0424	0.0008	18
		OTDG	0.4034	0.0081	12
		DLT	0.2735	0.0055	16
Customer service (CS)	0.27	FMPCN	0.5459	0.1474	2
		PTMCS	0.0224	0.0060	14
		CQT	0.4318	0.1166	3

Plan, source, manufacturing, delivery, and customer service are the main attributes for evaluating the SCP performance. Following the fuzzy AHP model (see Figure 5.3), all these attributes were compared to each other based on their importance for improving the SCP. The results presented in Table 5.8 show that plan attribute is the most important among all attributes with weight of 0.33 followed by manufacturing (0.28), and customer service (0.27), source (0.11), and delivery (0.02). It shows that there would be significant enhancement in SCP, if the firm focuses well on planning, manufacturing, and customer service attributes.

The relative weight of the attributes and sub-attributes are listed in Table 5.8. The most important sub-attribute under the plan attribute is customer order path as it has highest priority of 0.1701. It means the buying firm has to pay more attention on customer order path in supplier selection process. Weightage of other sub-attributes in plan category are order entry method (0.0629) and order lead time (0.0970). Under source attribute, buyer supplier relationship (0.0472) and supplier selection (0.0359) are the most important sub-attributes. Other sub-attributes in same category include purchase order cycle time (0.0024) and mutual assistance in solving problems

(0.0245). It implies that buyer-supplier relationship and supplier selection are very important for improving the performance of source in SC.

Under manufacturing attribute, capacity utilization, product cost, and quality are found very important sub-attributes that have weight of 0.0689. Weightage of other sub-attributes under manufacturing attribute are range of product and services (0.0345), effectiveness of master production schedule (0.0318), and flexibility (0.0069). Under delivery attribute, on time delivery of goods is most important (0.0081). Effectiveness of delivery invoice methods is the least important in this category with the weight of 0.0008. Weightage of other sub-attributes under delivery attribute are flexibility of delivery systems to meet particular customer needs (0.0056), and delivery lead time (0.0055). In customer service category, flexibility to meet particular customer needs (0.1474) and customer query time (0.1166) are found significantly important. Post transaction measures of customer service are found least important with the weight of 0.0060.

Table 5.8 also depicts the integrated weight of each and every sub-criterion. Integrated priority is also calculated by multiplying the weights of sub-attribute and respective attribute. For example, weight of OEM is 0.1907 and weight of respective attribute (i.e., plan) is 0.33. Hence the integrated priority of OEM is calculated by multiplying 0.1907 with 0.33 and it results 0.0629. Similarly the weight of each sub-attribute is calculated. Integrated weights are used to rank the sub-attribute on the basis of importance.

Table 5.9: Evaluation of the suppliers with respect to OEM

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.38,0.66,0.74)	(1.70,2.18,3.30
Supplier 2	(1.35,1.52,2.62)	(1,1,1)	(1.26,1.44,2.52)
Supplier 3	(0.30,0.46,0.59)	(0.40,0.69,0.79)	(1,1,1)

The weight vector from Table 5.9 is calculated as W_{OEM} = (0.48, 0.49, 0.03).

Table 5.10: Evaluation of the suppliers with respect to OLT

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.43,0.79,0.83)	(1.51,1.82,2.94)
Supplier 2	(1.20,1.26,2.33)	(1,1,1)	(1.41,1.73,2.83)
Supplier 3	(0.34,0.55,0.66)	(0.35,0.58,0.71)	(1,1,1)

The weight vector from Table 5.10 is calculated as W_{OLT} = (0.45, 0.51, 0.05).

Table 5.11: Evaluation of the suppliers with respect to COP

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1,1,2)	(1.35,1.51,2.62)
Supplier 2	(0.50,1,1)	(1,1,1)	(1.20,1.26,2.33)
Supplier 3	(0.38,0.66,0.74)	(0.43,0.79,0.83)	(1,1,1)

The weight vector from Table 5.11 is calculated as W_{COP} = (0.44, 0.40, 0.16).

Table 5.12: Evaluation of the suppliers with respect to SS

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.26,1.44,2.52)	(1.41,1.73,2.83)
Supplier 2	(0.40,0.69,0.79)	(1,1,1)	(1.59,2.08,3.17)
Supplier 3	(0.35,0.58,0.71)	(0.31,0.48,0.63)	(1,1,1)

The weight vector from Table 5.12 is calculated as W_{SS} = (0.52, 0.46, 0.02).

Table 5.13: Evaluation of the suppliers with respect to POCT

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.12,1.20,2,24)	(1.62,1.91,3.05)
Supplier 2	(0.45,0.83,0.89)	(1,1,1)	(1.35,1.51,2.62)
Supplier 3	(0.33,0.52,0.62)	(0.38,0.66,0.74)	(1,1,1)

The weight vector from Table 5.13 is calculated as W_{POCT} = (0.55, 0.42, 0.03).

Table 5.14: Evaluation of the suppliers with respect to BSR

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.26,1.44,2.52)	(1.41,1.73,2.83)
Supplier 2	(0.40,0.69,0.79)	(1,1,1)	(1.59,2.08,3.17)
Supplier 3	(0.35,0.58,0.71)	(0.31,0.48,0.63)	(1,1,1)

The weight vector from Table 5.14 is calculated as W_{BSR} = (0.52, 0.46, 0.02).

Table 5.15: Evaluation of the suppliers with respect to MASP

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.26,1.44,2.52)	(0.34,0.55,0.66)
Supplier 2	(0.40,0.69,0.79)	(1,1,1)	(0.38,0.66,0.74)
Supplier 3	(1.52,1.82,2.94)	(1.35,1.52,2.62)	(1,1,1)

The weight vector from Table 5.15 is calculated as W_{MASP} = (0.36, 0.05, 0.59).

Table 5.16: Evaluation of the suppliers with respect to EMPS

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.37,0.63,0.69)	(1.51,1.82,2.94)
Supplier 2	(1.45,1.59,2.71)	(1,1,1)	(1.26,1.44,2.52)
Supplier 3	(0.34,0.55,0.66)	(0.40,0.69,0.79)	(1,1,1)

The weight vector from Table 5.16 is calculated as W_{EMPS} = (0.44, 0.53, 0.03).

Table 5.17: Evaluation of the suppliers with respect to CU

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.41,1.73,2.83)	(1.35,1.51,2.62)
Supplier 2	(0.35,0.58,0.71)	(1,1,1)	(1.59,2.08,3.17)
Supplier 3	(0.38,0.66,0.74)	(0.31,0.48,0.63)	(1,1,1)

The weight vector from Table 5.17 is calculated as W_{CU} = (0.53, 0.44, 0.02).

Table 5.18: Evaluation of the suppliers with respect to PC

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.26,1.44,2.52)	(1.41,1.73,2.83)
Supplier 2	(0.40,0.69,0.79)	(1,1,1)	(1.26,1.44,2.52)
Supplier 3	(0.35,0.58,0.71)	(0.40,0.69,0.79)	(1,1,1)

The weight vector from Table 5.18 is calculated as W_{PC} = (0.55, 0.38, 0.07).

Table 5.19: Evaluation of the suppliers with respect to Q

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.12,1.20,2.24)	(1.41,1.73,2.83)
Supplier 2	(0.45,0.83,0.89)	(1,1,1)	(0.27,0.40,0.49)
Supplier 3	(0.35,0.58,0.71)	(2.05,2.50,3.68)	(1,1,1)

The weight vector from Table 5.19 is calculated as W_Q = (0.47, 0.03, 0.50).

Table 5.20: Evaluation of the suppliers with respect to F

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.40,0.69,0.79)	(0.34,0.55,0.66)
Supplier 2	(1.26,1.45,2.52)	(1,1,1)	(1.41,1.73,2.83)
Supplier 3	(1.52,1.82,2.94)	(0.35,0.58,0.71)	(1,1,1)

The weight vector from Table 5.20 is calculated as W_F = (0.07, 0.52, 0.41).

Table 5.21: Evaluation of the suppliers with respect to RPS

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.26,1.44,2.52)	(1.41,1.73,2.83)
Supplier 2	(0.40,0.69,0.79)	(1,1,1)	(1.41,1.73,2.83)
Supplier 3	(0.35,0.58,0.71)	(0.35,0.58,0.71)	(1,1,1)

The weight vector from Table 5.21 is calculated as W_{RPS} = (0.53, 0.42, 0.05).

Table 5.22: Evaluation of the suppliers with respect to FDSMPCN

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.40,0.69,0.79)	(0.34,0.55,0.66)
Supplier 2	(1.26,1.45,2.52)	(1,1,1)	(1.43,1.73,2.83)
Supplier 3	(1.52,1.82,2.94)	(0.35,0.58,0.71)	(1,1,1)

The weight vector from Table 5.22 is calculated as $W_{FDSMPCN}$ = (0.07, 0.52, 0.41).

Table 5.23: Evaluation of the suppliers with respect to EDIM

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.43,1.73,2.83)	(1.59,2.08,3.17)
Supplier 2	(0.35,0.58,0.71)	(1,1,1)	(1.12,1.20,2.24)
Supplier 3	(0.31,0.48,0.63)	(0.45,0.83,0.89)	(1,1,1)

The weight vector from Table 5.23 is calculated as W_{EDIM} = (0.67, 0.31, 0.02).

Table 5.24: Evaluation of the suppliers with respect to OTDG

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.35,0.57,0.71)	(0.45,0.83,0.89)
Supplier 2	(1.41,1.74,2.83)	(1,1,1)	(1.59,2.08,3.17)
Supplier 3	(1.12,1.20,2.24)	(0.31,0.48,0.63)	(1,1,1)

The weight vector from Table 5.24 is calculated as W_{OTDG} = (0.04, 0.56, 0.40).

Table 5.25: Evaluation of the suppliers with respect to DLT

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.5,1,1)	(0.34,0.55,0.66)
Supplier 2	(1,1,2)	(1,1,1)	(1.41,1.73,2.83)
Supplier 3	(1.52,1.82,2.94)	(0.35,0.58,0.71)	(1,1,1)

The weight vector from Table 5.25 is calculated as W_{DLT} = (0.16, 0.45, 0.40).

Table 5.26: Evaluation of the suppliers with respect to FMPCN

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(0.45,0.69,0.89)	(0.34,0.55,0.66)
Supplier 2	(1.12,1.45,2.24)	(1,1,1)	(1.26,1.44,2.52)
Supplier 3	(1.52,1.82,2.94)	(0.40,0.69,0.79)	(1,1,1)

The weight vector from Table 5.26 is calculated as W_{FMPCN} = (0.12, 0.46, 0.41).

Table 5.27: Evaluation of the suppliers with respect to PTMCS

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.26,1.44,2.52)	(0.24,0.32,0.47)
Supplier 2	(0.40,0.69,0.79)	(1,1,1)	(0.45,0.83,0.89)
Supplier 3	(2.14,3.17,4.15)	(1.12,1.20,2.24)	(1,1,1)

The weight vector from Table 5.27 is calculated as W_{PTMCS} = (0.28, 0.03, 0.70).

Table 5.28: Evaluation of the suppliers with respect to CQT

	Supplier 1	Supplier 2	Supplier 3
Supplier 1	(1,1,1)	(1.35,1.51,2.62)	(1.41,1.73,2.83)
Supplier 2	(0.38,0.66,0.74)	(1,1,1)	(1.41,1.73,2.83)
Supplier 3	(0.35,0.58,0.71)	(0.35,0.58,0.71)	(1,1,1)

The weight vector from Table 5.28 is calculated as W_{CQT} = (0.55, 0.42, 0.02).

Table 5.29: Summary combination of priority weights

Sub-attributes of plan				
	OEM	OLT	COP	*Alternative priority weight*
Weight	0.19	0.29	0.52	
Alternative				
Supplier 1	0.48	0.45	**0.44**	**0.4514**
Supplier 2	**0.49**	**0.51**	0.40	0.4491
Supplier 3	0.03	0.05	0.16	0.0994

Sub-attributes of source					
	SS	POCT	BSR	MASP	*Alternative priority weight*
Weight	0.33	0.02	0.43	0.22	
Alternative					
Supplier 1	**0.52**	**0.55**	**0.52**	0.36	**0.4822**
Supplier 2	0.46	0.42	0.46	0.05	0.3681
Supplier 3	0.02	0.03	0.02	**0.59**	0.1495

Sub-attributes of manufacturing							
	EMPS	CU	PC	Q	F	RPS	*Alternative priority weight*
Weight	0.11	0.25	0.25	0.25	0.02	0.12	
Alternative							
Supplier 1	**0.54**	**0.53**	**0.55**	0.47	0.07	**0.53**	**0.5001**
Supplier 2	0.53	0.44	0.38	0.03	**0.52**	0.42	0.3352
Supplier 3	0.03	0.02	0.07	**0.50**	0.41	0.05	0.1645

Sub-attributes of delivery					
	FDSMPCN	EDIM	OTDG	DLT	*Alternative priority weight*
Weight	0.28	0.04	0.40	0.27	

Alternative						
Supplier 1	0.07	**0.67**	0.04	0.16		0.1069
Supplier 2	**0.52**	0.31	**0.56**	**0.45**		**0.5085**
Supplier 3	0.41	0.02	0.40	0.40		0.3845
Sub-attributes of customer service						
	FMPCN	PTMCS	CQT			*Alternative priority weight*
Weight	0.55	0.02	0.43			
Alternative						
Supplier 1	0.12	0.28	**0.55**			0.3099
Supplier 2	**0.46**	0.03	0.42			**0.4376**
Supplier 3	0.41	**0.70**	0.02			0.2523
Main attributes of the goal						
	P	S	M	D	CS	*Alternative priority weight*
Weight	0.33	0.11	0.28	0.02	0.27	
Alternative						
Supplier 1	**0.4514**	**0.4822**	**0.5001**	0.1069	0.3099	**0.4234**
Supplier 2	0.4491	0.3681	0.3352	**0.5085**	**0.4376**	0.4069
Supplier 3	0.0994	0.1495	0.1645	0.3845	0.2523	0.1695

The results presented in Table 5.29 show that the priority weight of supplier 1 is the highest weight (0.4234) among all three suppliers. Therefore, supplier 1 is selected based on alternative priority weight and performance. The weight of supplier 2 and supplier 3 are 0.4069 and 0.1695 respectively. Though, priority weight of supplier 2 is very near to supplier 1. Conversely, the overall performance of supplier 3 is not satisfactory. In-depth analysis of results shown in Table 5.29 provides clear picture about the performance of all three suppliers on various attributes and sub-attributes. For example, in plan attribute, supplier 1 performance is best with the overall weight of 0.4514 followed by supplier 2 (0.4491). However, on the basis of sub-attributes of plan category, supplier 2 is performing well on OEM and OLT compared to supplier 1. Supplier 1 is ahead only in one sub-attribute of plan which is COP. Since, the final result for supplier performance on plan attribute comes by adding the multiplied value of suppliers' weight with the weights of sub-attributes.

Similarly, the performance of suppliers on each and every attribute and sub-attribute is illustrated in Table 5.29. Supplier 1 is found best in the plan, source, and manufacturing performance whereas supplier 2 is found best for the delivery and customer service performance. Bottom part of Table 5.29 gives the final value of suppliers' weights as discussed above. It is clearly evident from the results that the final ranking of the suppliers is highly depends on the weights of attributes of SCP.

5.5 Conclusion and managerial implications

In this chapter, we have developed a fuzzy AHP based model for supplier selection under multiple criteria settings. Five attributes (such as plan, source, manufacturing, delivery, and customer service) were identified based on literature review and experts' opinion that affect firm's SCP. Further, 20 sub-attributes were identified for the aforementioned five SCP attributes. Based on the identified attributes and sub-attributes a brainstorming session was conducted with six experts from an Indian automotive company located in North India. To illustrate the proposed model a cohort of three suppliers is considered. The experts were asked to compare the suppliers against each SCP attribute and sub-attribute. Finally, suppliers were raked based on the overall weightage. The raking results show that supplier 1 is the best supplier in terms of attributes and sub-attributes compared to other two suppliers.

This proposed model also provides information on the most appropriate supplier for improving the overall SCP. Managers have the freedom to include the customized SCP attributes and sub-attributes based on the type of industries and specific problems under consideration. This model can also be used to review current supplier selection problem. Finally, this study helps to decision makers in reducing a base of potential suppliers to a manageable number and make the supplier selection by means of multi-criteria techniques.

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CHAPTER 6
Research Methodology

Preview

This chapter accomplishes the fourth objective of this research which is based on developing a scale for measuring the overall supply chain performance. It describes the outlay of a quantitative research to validate the proposed model and for the validation and assessment of variables; a scale development procedure has been followed. Further, this chapter discusses in brief about the research methodology, research design, data collection methods, scaling techniques, questionnaire design, sampling design, data collection and analysis procedures used in different phase of scale development process.

6.1 Introduction

For any empirical research, theoretical base is very important. It may be either theory development (exploratory) or theory verification (confirmatory) or may be the combination of both (Flynn *et al.*, 1990). Based on the literature review presented in Chapter 2, a conceptual framework was also presented in Figure 2.3 (see Chapter 2). Chapter 2 deals literature classification and various research gaps that need to be addressed in future researches. The discussion how these gaps can be fulfilled in the present and future studies is a matter of anxiety. These gaps spin around a few areas like first area entails defining the objective of the present study. The second area tells the definition and measurement constructs. Plan performance, source performance, manufacturing performance, delivery performance, and customer service performance are the five constructs for measuring the overall SCP in any manufacturing firm. This chapter provides the research methodology adopted for developing the research instrument like nature of the sample, design of study, types of respondent and firm while Chapter 7 discusses about the entire part of this methodology development process.

6.2 Scale development process

A well-defined scale development procedure has been proposed by Churchil (1979). Further, this method was developed by various researchers (e.g. Bentler and Bonnet, 1980; Peter, 1981;

Nunnally and Bernstein, 1994). Scale development process contains two phases those are – item generation and selection phase (qualitative inquiry stage) and another one is scale refinement phase (see Figure 6.1). Qualitative inquiry stage was used for developing and removing the constructs and items from literature and expert survey. These are content analysis and categorization, generation of initial pool of items, and assessment of content and face validity through experts' opinion. Further, scale refinement phase consists of purification stage. Purification stage includes confirmatory factor analysis, unidimensionality and reliability assessment, and convergent and discriminant validity assessment. These steps have been followed for the development of scale. A detail of the scale development process is presented in next chapter. The subsequent part of this chapter provides an overview of research methodology adopted for the scale development.

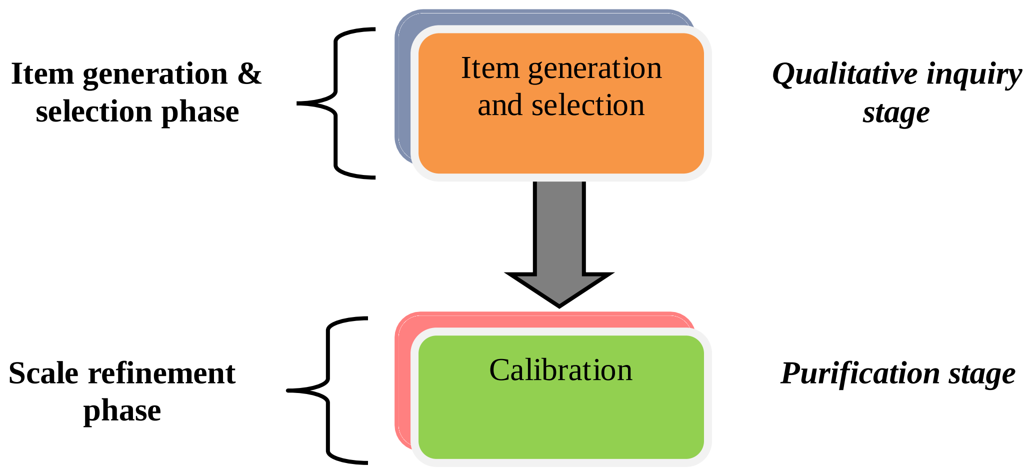

Figure 6.1: Scale development procedure

6.3 Research methodology

The purpose of research methodology is to guide the researchers to achieve the objectives of the study. It plays a vital role and gives a base to solve the research problems (Tsang and Antony, 2001). The basic steps of research methodology used in the present study as proposed by Malhotra and Dash (2009) are given in Figure 6.2. It contains various steps like research design, data collection methods, scaling technique, questionnaire design, sampling design, data collection procedure, and data analysis procedure. All these steps are discussed in details in the subsequent sections of this chapter.

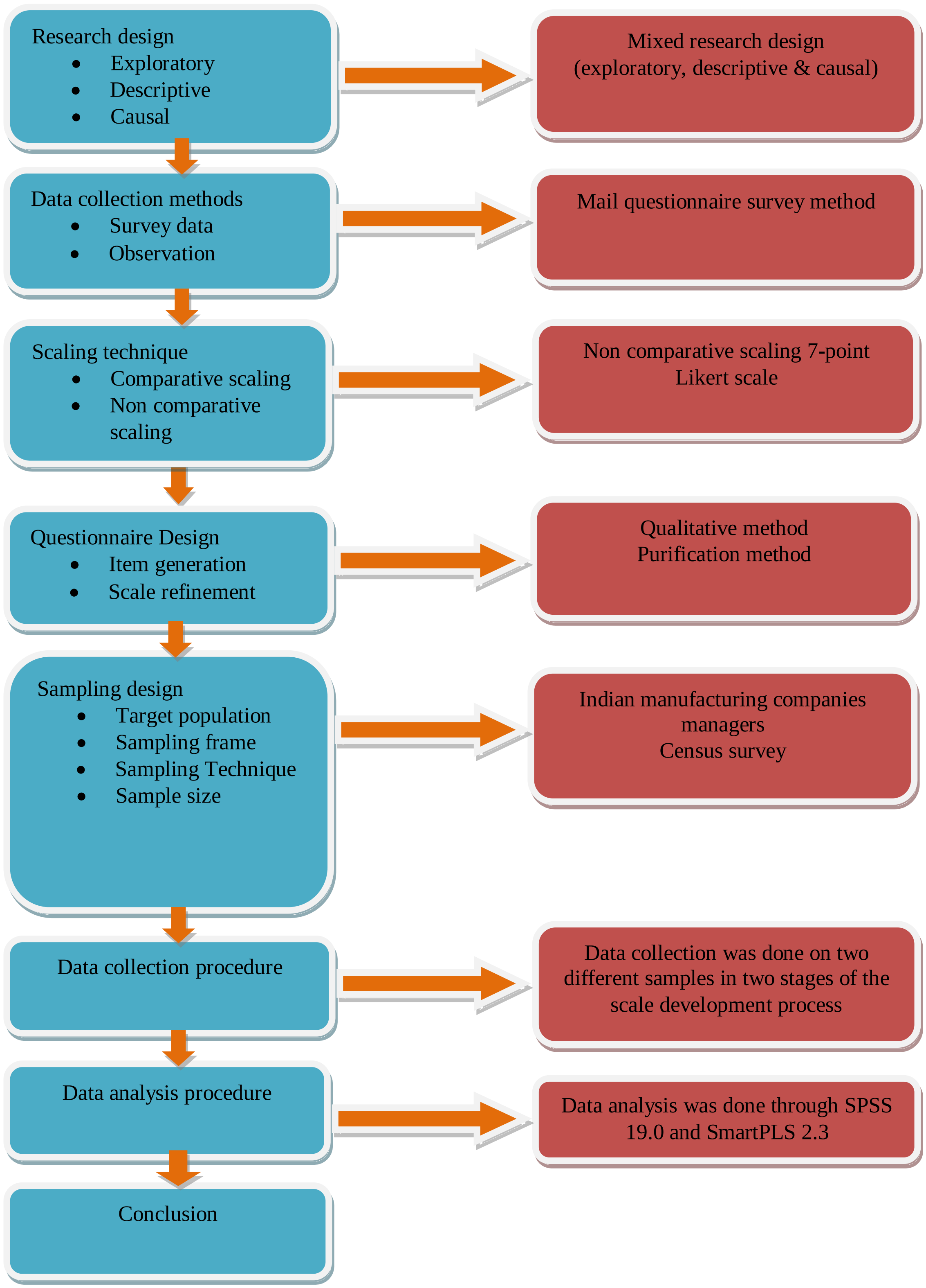

Figure 6.2: Overview of research methodology followed in the present research

6.4 Research design

The research design is the initial step of the research methodology and draws a sketch for the entire study. “A research design is the logical chain that connects the empirical data to the study’s initial research questions and ultimately its conclusions” (Yin, 1994). There are three categories of research design suggested by Malhotra and Dash (2009) i.e. exploratory, descriptive, and causal. Exploratory research comprises a comprehensive study of literature on SCPM and has been used to achieve the objectives of the present study. Secondly, the research design adopted in this study was also cross sectional descriptive in nature. The present study used multiple cross sectional research design. Cross sectional study is also necessary for scale development purpose. Third, causal research design is very helpful to understand the correlation between independent and dependent variables. In the present study, overall SCP is the dependent construct/variable and plan, source, manufacturing, delivery, and customer service performance act as the independent constructs/variables. Finally in brief, a mixed approach of all these three research design has been implemented in the present study. Such approach offers holistic and a structured preview of the research problem. According to Amaratunga *et al.* (2001), these three designs are complement to each other in nature and support as well.

6.5 Data collection methods

Data were collected by different methods during earlier researches. Some prior researchers collected data from various agencies (Herremans *et al.*, 1993; Ruf *et al.*, 2001; Simpson and Kohers, 2002; Hong *et al.*, 2009). But in developing countries it is very hard to get these types of agencies (Mishra and Suar, 2010). In another method, researchers adopted content analysis approach of corporate disclosure (Jacobs *et al.*, 2010; Chang and Kuo, 2008). The third approach used by the researchers was the collection of long-lasting data with the help of a questionnaire from the employees of respective companies (Klassen and Vachon, 2003; Rao and Holt, 2005; Seuring and Muller, 2008; Turker, 2009; Gupta *et al.*, 2009; Rettab *et al.*, 2009; Mishra and Suar, 2010). Such kind of survey is having many advantages like respondents people become most aware of the problem and information is easily available to them. Second benefit is that as researchers promise to keep the privacy of the respondent and the chances of biasness in their opinion will be least. In addition, various researchers also adopted questionnaire method for data collection in this field of study (Benito and Benito, 2005; Turker 2009; Mishra and Suar, 2010). There is another benefit of using the questionnaire method is that this method is relatively cheap, accurate, covers a wide range, and quick in data collection (Zikmund, 2000; Creswell, 2003). Moreover, an online survey is a better approach for internal consistency and predictive validity (Sethuraman *et al.*, 2005). But there are some disadvantages of using this online survey method like unavailability of internet among the population of interest (Schillewaert and Meulemeester, 2005).

6.6 Scaling techniques

Scaling techniques are classified into comparative and non comparative scales. To achieve the fourth objective of this thesis, data were collected with the help of a structured questionnaire on 7-point Likert scale. There are some advantages behind the using of this Likert scale like easiness in construction and administration of the research. Also, it is suitable for personal, e-mail and telephonic interview (Malhotra and Dash, 2009). Prior authors also used this Likert scale in their study of supply chain (Zsidisin and Hendrick, 1998; Ageron *et al.*, 2012; Smerecnik and Anderson, 2011).

6.7 Questionnaire design

Questionnaire design was started with the generation of an initial collection of constructs and key factors from the existing literature and experts' opinion. Initially, 73 factors/items were generated from the existing literature of SCPM. In the next step, experts were invited to examine the group of constructs and factors. Experts advised to keep only properly significant factors related to SCPM. Thus, experts removed 49 factors; and final remained were 24 factors. As they suggested that, 49 factors are unclear and vague or having the same implication from other factors. Next to this, following a similar approach as Lin and Hsieh (2011), experts were called for to rank the factors/items one out of three categories i.e. "not representative", "somewhat representative" or "clearly representative". *"Only items rated clearly and somewhat representative by at least 80 percent of the judges were retained"* (Lin and Hsieh, 2011). Finally, a questionnaire of 24 key factors was developed in which 4 key factors were related to SCP construct and remaining other 20 key factors were related to plan, source, manufacturing, delivery, and customer service performance. These key factors were checked for the validity and reliability. Detail of these activities has been given in the next Chapter 7.

6.8 Sampling design

Sampling design is the next step after the questionnaire design to select the suitable sample for the collection of data to achieve the objective of this study. There are numerous techniques to decide a sample size according to the requirements. Sampling techniques are broadly divided into two categories i.e. probability sampling and non probability sampling. There are five steps suggested by Malhotra and Dash (2009) in the sampling design process. These steps are target population, determination of sampling frame, selection of sampling technique suitable for the particular study, an estimation of the sample size and last but not least the execution of sample process. The main concern during the sample selection is whether research should be industry specific or not. There may be an argument for focusing on a particular industry.

6.8.1 Target population

The target population is defined in terms of elements, sampling unit, time, and extent (Malhotra and Dash, 2009). The Target population for the present study is described as below:

Elements – Managers;

Sampling unit – Automotive sector;

Time – July 21, 2011 – January 13, 2012;

Extent- India.

6.8.1.1 Elements – Managers

Through questionnaire survey, primary data were collected for the present study. The elements of the study are managers of Indian automotive industries. The managers were selected on the basis of two criteria. Firstly, selection of managers as the element of the target population often creates the problem of response bias (Wang and Dewhirst, 1992). The use of middle level managers as the elements of analysis will provide insights on a firms' real action as observed by internal stakeholders but not the strategy maker. The second reason for the selection of managers was that they could provide the appropriate information about the firm's SC process.

6.8.1.2 Sampling unit – Why automotive sector?

Automotive sector was selected as sampling unit of the study for a variety of reasons. There are number of studies available on the automotive sector across the globe for the assessment of SCP using different techniques (Koplin *et al.*, 2007; Zhu *et al.*, 2007; Sarkis *et al.*, 2010). But most of the studies belong to the developed countries and it is very emerging period in the developing countries. Such studies are still in the stage of infancy in the case of emerging economies like India. Now, automotive sector has turned up as a sunrise sector and one of the top ten in the Indian economy in a short period of five decades (Joshi *et al.*, 2013; Sardy and Fetscherin, 2009). This was the prime reason to conduct this study for Indian automotive sector. Today, India is growing as one of the world's fastest growing passenger car markets and the second largest manufacturer of two wheelers. Thus, international and Indian firms are trying to develop latest technologies for improving the SCP. According to Joshi *et al.* (2013), the Indian automotive sector desiring to increase their competitiveness in the global marketplace and the global auto assemblers, are looking forward to Indian auto part firms as potential supply chain partners. Moreover, the key factors of SCP activities have become a matter of major concern for identifying the importance of the automotive sector for national competitiveness, and these factors are known as performance indicators (Joshi *et al.*, 2013). The role of the automotive sector in India's GDP (more than 10%) has been a phenomenon and is one of the fastest emerging sectors in India. Therefore, this sector is recognized as one of the drivers of economic growth as it contributes significantly to the overall GDP of the country (Burange and Yamini, 2008). Burange and Yamini (2008) also mentioned that international automotive firms are looking towards India not only for its emerging market but also as an efficient supplier base. Finally, where does India stand?

Largest tractor manufacturer

2nd largest two wheeler manufacturer

2nd largest bus manufacturer

5th largest heavy truck manufacturer

6th largest car manufacturer

8th largest commercial manufacturer

(Source: ACMA Annual Report, 2014)

6.8.2 Sampling frame

Sampling frame represents the elements of the target population. It contains the list of guidelines to mark the target population (Malhotra and Dash, 2009). In this study, Indian automotive industries are the target population. The list of automotive companies was retrieved from the directory of Automobile Component Manufacturing Association of India (ACMA Annual Report, 2014), Society of Indian Automobile Manufacturers (SIAM Annual Report, 2014), and other relevant sources. Many prior studies used the data from industry specific association for developing a sampling frame (Klassen and Vachon, 2003; Clemens and Douglus, 2006; Olorunniwo and Li, 2010).

6.8.3 Sampling technique

For the second refining and validation stage, census survey method was used in the present study (Turker, 2009; Muller and Kolk, 2009). The sampling technique was different for the different stage of the scale development.

6.8.4 Sample size

The desirable sample size (n) should be:

$$n > 50 + 8V$$

where 'V' is the number of independent variables for testing the multiple regression.

Hair *et al.* (1998) suggested that sample size could have an effect on the generalizability of the results. The desirable ratio should be in the range of 15 to 20 for each independent variable. However, a lower ratio like 5:1 could also be considered (Hair *et al.*, 1998). Moreover, there is difference in suggestion provided by many authors based on the statistical test used in the research. Tabachnick and Fidell (2001) suggested the minimum sample size should be 300 for the factor analysis. Nunnally (1978) suggested that number of case should be in the ratio of 1: 10 to ensure the factor reliability. According to Hair *et al.* (2006) for structural equation modeling (SEM) the minimum sample should be 150. Various past studies have also been done on the basis of methodology, sample size, and techniques applied from different companies (Benito and Benito, 2005; Turker, 2009; Rettab *et al.*, 2009) (see Table 6.1). Figure 6.3 shows the total number of collected responses 226 (sample size) for this study.

6.9 Data collection procedure

In this study, primary data were collected for two stages of scale development process. Standard validity and reliability was assessed at the initial stage. This was just a preliminary assessment or initial refinement stage of the scale. In this, second stage was purification and validation stage. Further, primary data were collected through structured questionnaire and personal visits to the Indian automotive buyers association. In the beginning, questionnaire was sent to more than 200 managers of respective companies through e-mail along with a cover letter of supervisor

(Appendix A). Cover letter contained introduction of researcher and purpose of the research. Different approaches were used in order to get responses from the respondents and also were guaranteed for privacy of their data and were free to fill online survey. After seeing the negligible responses from online survey, it was decided to go personally different parts of the Indian automotive centers and then visited on the Indian automotive buyer's location. These automotive companies were located in different parts of the India and data were collected basically from six automotive focal point including Haridwar, Delhi (NCR), Indore, Rudrapur, Ludhiana and Baddi. Finally, data were collected in approx. 6 months during the period of July 21, 2011 to Jan 13, 2012 (see Table 6.2). In 6 months, more than 1000 automotive companies were visited in all these automotive hub or centers in different time period as mentioned above and finally got 226 responses (about 22.6 percent). Therefore, the sample size for the study is 226. Final structured questionnaire is attached in (Appendix B).

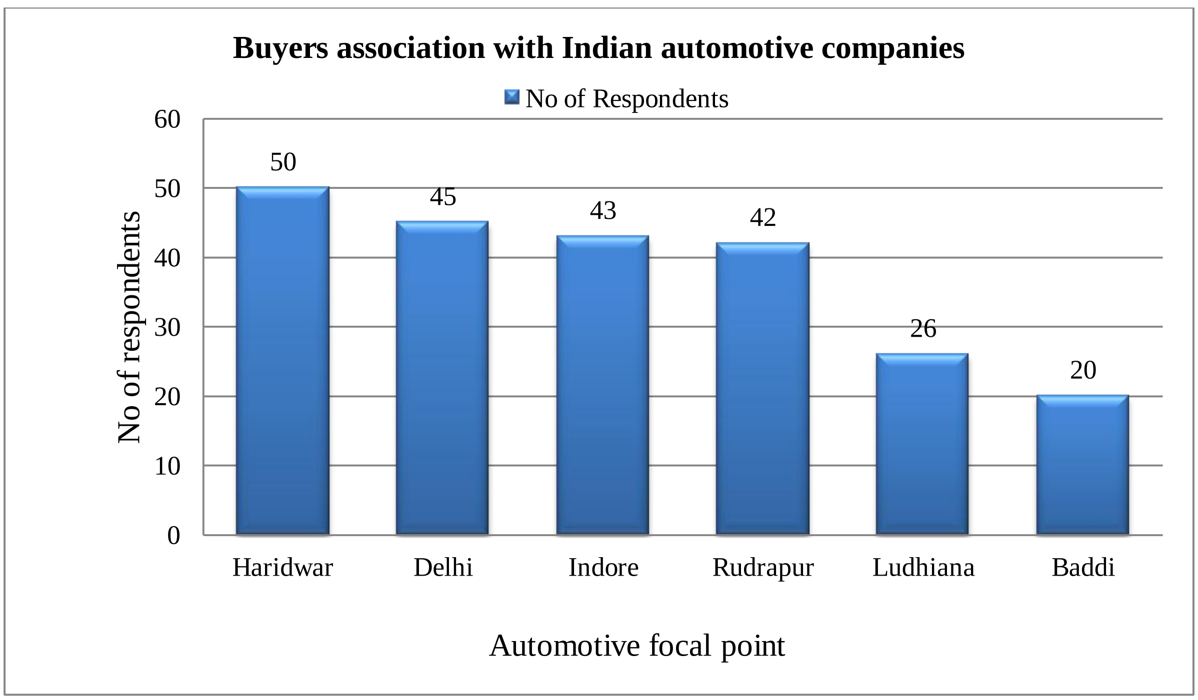

Figure 6.3: Buyers association with automotive companies

Table 6.1: Review of past research							
Authors	*Approach*	*Type of Respondents*	*Methodology/ Sampling Type*	*Usable Sample Size*	*Scale Used*	*Technique Applied*	*Items Identified*
Maignan and Ferrell (2000)	Questionnaire	Managers	Random	330	---	Factor analysis	4 factors, 18 items
Benito and Benito (2005)	Questionnaire	Managers	Census	186	6 Point scale	Correlation	4 factors, 29 items
Fraj-Andre´s *et al.* (2009)	Questionnaire	Managers	Census	361	5 Point scale	SEM	2 factors ,25 items
Muller and Kolk (2009)	Questionnaire	Managers	Census	93	5 Point scale	Regression	3 factors, 7 items
Poolthong and Mandhachitara (2009)	Questionnaire	Customer	Convenience sampling	275	5 Point scale	Factor analysis	4 factors, 14 items
Rettab *et al.* (2009)	Questionnaire	Managers	Census	280	5 Point scale	Factor analysis	6 factors, 26 items
Turker (2009)	Questionnaire	Managers	Census	269	7 Point scale	Factor analysis	4 factors, 18 items
Mishra and Suar (2010)	Questionnaire	Managers	Random sampling	150	5 Point scale	Factor analysis	6 factors, 61 items
Mandhachitara and Poolthong (2011)	Questionnaire	Customers	Convenience	275	5 Point scale	SEM	4 factors, 14 items
Felicio *et al.* (2012)	Questionnaire	Managers	Random	217	5 Point scale	Factor analysis	6 factors, 21 items

Table 6.2: Automotive cluster-wise responses received

Automotive focal point in India	*July 2011*	*August 2011*	*September 2011*	*October 2011*	*November 2011*	*December 2011*	*January 2012*	*Total*
Haridwar	5	24	21	---	---	---	---	*50*
Delhi (NCR)	---	---	37	8	---	---	---	*45*
Indore	---	----	---	25	---	18	---	*43*
Rudrapur	---	---	---	---	42	---	---	*42*
Ludhiana	---	---	---	---	---	26	---	*26*
Baddi	---	---	---	---	---	---	20	*20*
Total Responses Received	*5*	*24*	*58*	*33*	*42*	*44*	*20*	*226*

6.10 Data analysis procedure

Meena and Sarmah (2012) stated that basically two methods are used in the literature to estimate structural model i.e. LISREL based structural equation modeling (SEM) also called covariance based SEM and the other one is PLS which is variance based approach developed by Wold (1985). In this study, we have used partial least square (PLS) as opposed to SEM as it requires smaller sample size to test the conceptual model and associated hypotheses (Chin, 1998a). This method does put minimum criteria on measurement scale, sample size (Chin *et al.*, 2003) not like AMOS or LISREL. The minimum sample size should be 10 times more than the number of items. SEM efficiently works in the case of reflective kind of models (Chin and Newsted, 1995).

PLS is an effective and helpful method to handle the small sample size as compared to number of variables. In addition, it handles the missing values also. Further, this approach does not require data to be normally distributed and measured on interval scale (Fornell and Cha, 1994; Wold, 1985). The software used for the analysis is SmartPLS, Version 2.0 M3, an open-source software package which is provided by the University of Hamburg (Ringle *et al.*, 2005). To estimate the significance path coefficients and item loadings, a bootstrapping approach is used where 500 random samples of observations with replacements are generated from the original dataset (Chin, 1998a). Item loadings and path coefficients are re-estimated for each variable and t-statistics are calculated for each construct. The PLS produced coefficients of multiple determination (R^2) for all endogenous constructs in the model. The essential step to test the theoretical models is to assess the accuracy of the measurement model. The strength of the measurement model for constructs with reflective measure is assessed by looking at individual item reliability, internal consistency and discriminant validity.

This technique has been applied in different areas of management and related other areas like marketing, consumer psychology, human resource management, CSR (Fornell *et al.*, 1990; Hulland, 1999; Pavlou and Fygenson 2006; Sarstedt, 2008; Sosik *et al.*, 2009). This technique has been used considerably where either the lower numbers of responses were expected or the large sample collection was not possible. As a rule of thumb, the minimum sample size required for the PLS is 100 (Chin, 1998a; Barclay *et al.*, 1995).

6.11 Conclusion

This chapter is based on scale development for measuring the SCP in the Indian automotive industry. To validate proposed model in Chapter 2, an outline of the scale development process is presented. Later sections of this chapter provide a brief detail of the steps of the research methodology applied for the development of measurement and structural models. These steps include the research design, data collection methods, scaling techniques, questionnaire design, sampling design and data analysis procedure. A detailed description of the data analysis process is given in the subsequent chapter of the present study.

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CHAPTER 7
Measurement of a Supply Chain Performance Model

Preview

The objective of this chapter is to develop a model for measuring supply chain performance in the Indian automotive industry. In this objective, a scale development process was pursued at the different stages. Outcome of this study presents a good overview of various supply chain performance measurement constructs and their key factors. Moreover, this study will also help the managers to improve and make efficient their firm's supply chain performance.

7.1 Introduction

Since last two decades, supply chain performance measurement (SCPM) has been receiving continual attention from the researchers as well as practitioners. Nowadays, supply chain management (SCM) plays a vital role in improving the effectiveness, efficiency, customer service, and profit for manufacturing and service industries (Gunasekaran *et al.* 2001; Chia *et al.*, 2009). Performance measurement (PM) is an effective tool that helps firms in improving the overall performance of their supply chain (SC) (Neely *et al.*, 2002; Shepherd and Gunter, 2006; Bhattacharya *et al.*, 2014). Therefore, it is mandatory for firms to focus on SCPM, as it covers the entire interdependencies cross the borders of firms (Beamon, 1999; Shepherd and Gunter, 2006). Gunasekaran *et al.* (2004) proposed a framework to measure supply chain performance (SCP) at operational, tactical and strategic levels.

In today's business environment, a long-term relationship between the different partners of SC is very crucial for improving the overall SCP (Charan *et al.*, 2008). Although most of the industries have realized the importance of long-lasting relationship with their partners, however, many of them still do not have effective strategies for achieving it. According to Hampel-Milagrosa *et al.* (2013; 2015), any business growth is possible when management develops right and effective strategies. Saad and Patel (2006) analyzed the structure of SCP measures and the difficulty of implementing them in the Indian automotive industry. They found that the Indian automotive industries are not implementing the important concepts of SCPM properly. In past few years, some attempts have been made from the Indian perspectives to measure SCP at industry level. However, only a few of them have actually implemented.

The recent opening of foreign investments in the automotive sector has emanated many overseas companies like Toyota, Volkswagen, Honda, and Ford etc. to invest in the Indian market (Burange and Yamini, 2008; Joshi *et al.*, 2013). Consequently, it has fuelled competition among the different automotive companies in terms of cost, quality, delivery, and flexibility. To compete, companies are trying to improve the overall performance of their SC.

Many studies have been conducted on SCPM from different perspectives (Beamon, 1999; Brewer and Speh, 2000; Neely *et al.*, 2002; Gunasekaran *et al.*, 2004; Ren *et al.*, 2004; Park *et al.*, 2005; Shepherd and Gunter, 2006; Yeh *et al.*, 2007; Choy *et al.*, 2007; Bhagwat and Sharma, 2007; Chia *et al.*, 2009). Most of the published work on SCPM is conceptual and empirical in nature. Recently, Dey and Cheffi (2013) proposed holistic constructs for green SCPM that cover the entire SC network. However, there is dearth of literature on exploring the factors that's affect SCP in the Indian automotive industry (Charan *et al.*, 2008; Ganga and Carpinetti, 2011). The above reviewed studies show that there is an urgent need to develop a model for identifying the factors that affect SCP.

In this chapter, we have made an attempt to develop a scale and model to measure SCP of the Indian automotive industry, which would impart knowledge about the current level of SCP on various activities and would assist the SC managers to focus on areas that need further improvement. This chapter covers the fourth objective that was stated in Chapter 1. First, we identified the constructs and their factors that affect SCP based on literature review and discussion with experts from the Indian automotive industry. Second, a questionnaire is designed based on these identified factors and a survey was conducted among 226 Indian automotive firms. Partial least square (PLS) approach was used to validate the model and investigate the relationships of constructs with overall SCP.

The remainder of the chapter is organized as follows. Section 7.2 presents the research framework and conceptual model for SCP. Section 7.3 briefly discusses the research instrument and data collection. Section 7.4 and Section 7.5 discuss the measurement and structural model results. Results and managerial implications are presented in Section 7.6 and finally, conclusion is provided in Section 7.7.

7.2 Research framework and conceptual model of SCP

Based on the experts' opinion and literature review, it was found that plan performance, source performance, manufacturing performance, delivery performance, and customer service performance are the constructs that affect overall SCP in the Indian automotive industry. The conceptual model and related hypothesis are shown in Figure 7.1. The arrow depicts the relationships among constructs and with supply chain performance.

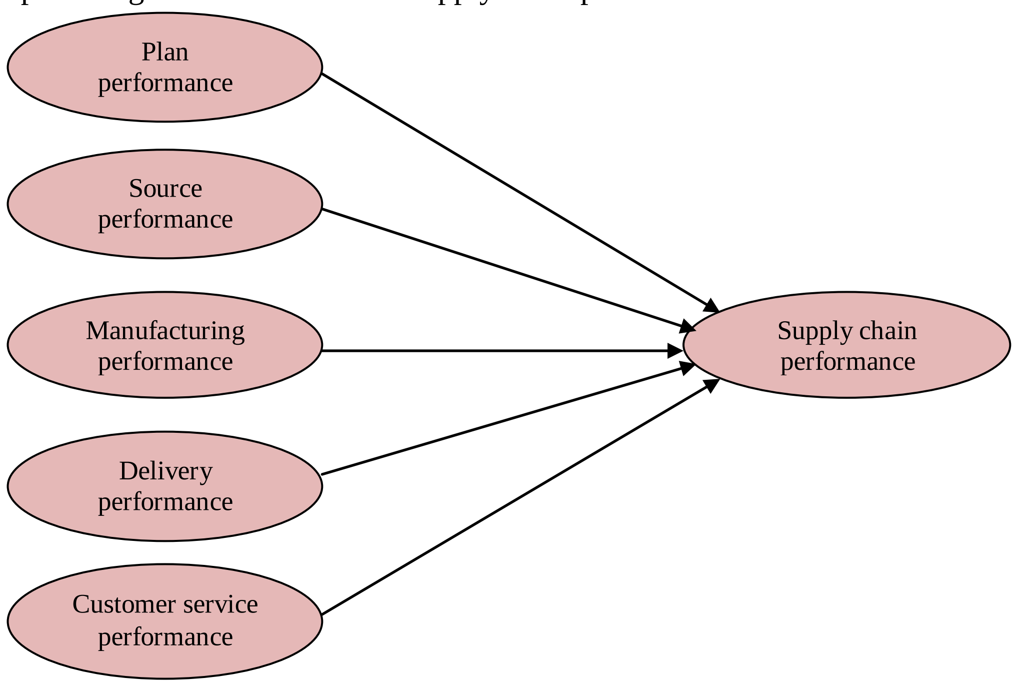

Figure 7.1: Conceptual model and associated hypotheses

7.2.1 Plan performance and SCP

For any industry, the initial activity starts with planning of purchase order and it affects the inventory level and downstream activities of SC (Bhagwat and Sharma, 2007). Therefore, the first activity that affects the firm's SCP is right planning for placing and receiving the orders. In other words, companies must ensure that their order processing is properly designed and managed with all other activities of SC. In order to have a good planning process, the performance of activities such as order entry method, order lead time, and customer order path needs to be measured (Gunasekaran *et al.*, 2001; Bhagwat and Sharma, 2007). Moreover, environmental planning, management commitment, environmental performance and operational performance are key constructs for overall SCP (Ren *et al.*, 2004; Dey and Cheffi, 2013). Therefore, the following hypothesis is developed:

H_1: Plan performance has positive impact on the firm's overall SCP.

7.2.2 Source performance and SCP

Source performance is one of the most important parameters in SC from supplier selection and buyer-supplier relationship perspectives. Sourcing facilitate procurement of goods and services from suppliers to meet the planned or actual demand of the customer. Nowadays, a strong buyer-supplier relationship is need of the hour. The United State food industry reported $30 billion annual wastage due to poor buyer-supplier relationship (Fisher, 1997; Gunasekaran *et al.*, 2001). Many studies have emphasized the importance of strong buyer-supplier relationships/partnerships for better SCP (Ellram, 1991; MacBeth and Ferguson, 1994; De Toni *et al.*, 1994; New, 1996; Towill, 1997; Bhagwat and Sharma, 2007; Rinehart et al. (2008); Meena and Sarmah, 2012). Bhagwat and Sharma (2007) showed the importance of factors such as supplier selection, purchase order cycle time, buyer-supplier relationship, and mutual assistance to improve sourcing performance.

Selection of appropriate supplier(s) and effective buyer-supplier relationship management are the key factors for increasing the competitiveness of firm (Ghodsypour and O'Brien 2001; Choy *et al.*, 2003a; Aksoy and Ozturk, 2011; Meena and Sarmah, 2012). According to Sarkar and Mohapatra (2006), suppliers significantly contribute in SCP improvement. Supplier selection is generally done based on the performance criteria such as product cost, product quality, and delivery times (Braglia and Petroni, 2000; Viswanadham and Samvedi, 2013). In addition, strong relationships among SC partners make things easier in terms of product information, reliability, product delivery, quick response, flexibility, and cost (Keebler and Plank, 2009; Aksoy and Ozturk, 2011). In today's fierce business environment, there is a significant need to assess and improve the relations among SC partners as these influences the overall SCP (Gunasekaran *et al.*, 2001; Bhagwat and Sharma, 2007; Viswanadham and Samvedi, 2013). Nawrocka *et al.* (2009) suggested that building the close relationships with good operational partners is crucial for implementing environmental initiatives and SCP improvement. Bhattacharya *et al.* (2014) showed that the internal operations and SCP of firms are dependent on suppliers' activities. Dey and Cheffi (2013) mentioned that today's firms green SCP depends on supplier relationships. Therefore, we construct the following hypothesis:

H_2: Source performance has positive impact on firm's overall SCP.

7.2.3 Manufacturing performance and SCP

Manufacturing process converts raw materials into final product. The performance of manufacturing/operations process significantly influences the firm's and SCP (Lambert and Pohlen, 2001; Ren *et al.*, 2004; Dangayach and Deshmukh, 2006; Ramkumar *et al.*, 2013). Many authors have shown that attributes such as effectiveness of master production schedule, capacity utilization, product cost, quality, flexibility, and range of product and services significantly affect manufacturing performance (Skinner, 1969; Hill, 1987; Gerwin, 1993; De Toni and Tonchia, 1998; Bhagwat and Sharma, 2007; Lin *et al.*, 2011).

Furthermore, various other factors like speed of delivery, product quality, delivery reliability, and flexibility also affect SCP (Slack *et al.*, 1995; Mapes *et al.*, 1997). According to Chibba (2007), manufacturing performance of a firm also affects its SCP. Viswanadham and Samvedi (2013) stated that manufacturing and distribution processes significantly influence customer's satisfaction and SCP. The aforementioned literatures suggest that better performance of manufacturing process positively influence the overall SCP. So we construct the following hypothesis:

H_3: Manufacturing performance has positive impact on firm's overall SCP.

7.2.4 Delivery performance and SCP

Delivery process provides finished goods and services to meet the customer demand and it usually includes effective transportation and distribution management. Viswanadham and Samvedi (2013) indicated that delivery of product with minimum cost at right time to customers improves SCP. In any SC, there are some attributes such as flexibility of delivery systems, effectiveness of delivery invoice methods, and delivery lead time, etc. that affect the delivery and SCP significantly (Novich, 1990; Gelders *et al.*, 1994; Stewart, 1995; Gunasekaran *et al.*, 2001). The aforementioned measures are the heart of any delivery system's performance (Gelders *et al.*, 1994; Gunasekaran *et al.*, 2001; Chibba, 2007). The retailer or distributor of a firm also has significant impact on overall SCP as compared to suppliers and manufacturer (Lambert and Pohlen, 2001). The performance of internal and external delivery of goods and services affects the overall performance of any system (Gunasekaran and Kobu, 2007; Ganga and Carpinetti, 2011). Thus we hypothesize:

H_4: Delivery performance has positive impact on firm's overall SCP.

7.2.5 Customer service performance and SCP

Customer service process is associated with receiving or returning products from the buyers. In current business environment, customer satisfaction is extremely important (Srivastava and Sharma, 2013). An unsatisfactory customer service process may force the customer to leave the business (Gunasekaran *et al.*, 2004; Meena and Sarmah, 2012). Customer satisfactory is one of the significant factors that affect buyer's performance as well as overall SCP (Dey and Cheffi, 2013). Since, SCP of any firm depends on customer service process. Customer service performance basically contains flexibility to meet the customer needs, after sales service, and response time to customer's queries (Bhagwat and Sharma, 2007). Nowadays, performance of SC is measured by different metrics of SC, customer relationship management, and customers' service performance (Lee and Billington, 1992; Van Hoek, 2001; Dey and Cheffi, 2013). Moreover, if a firm provides better customer service as compared to its competitors, more customers will be attracted for getting its products or services. So we construct the following hypothesis:

H_5: Customer service performance has positive impact on firm's overall SCP.

7.3 Research instrument and data collection

The SCP model consist the aforementioned constructs that are derived from literature review and experts opinions and these constructs may differ from industry to industry. The constructs of SCP model are unobservable (latent) variables or constructs (i.e., plan performance, source performance, manufacturing performance, delivery performance, customer service performance) indirectly described by a block of observable variables, which are called manifest variables or factors/indicators. These constructs and their observable variables or factors/indicators are given in Table 7.1. The use of multiple items (questions) for each construct increases the accuracy of the estimate, compared to an approach of using a single item. To develop a multiple items scale for each construct, most of the steps were followed (except fourth and fifth steps) recommended by Churchill (1979). In questionnaire survey, the evaluation of the postulated items of each construct was conducted using a 7-point Likert scale (Magidson, 1994) that ranged from extremely unimportant to extremely important.

Table 7.1: The latent variables and their observable indicators in the model

Latent variables/constructs	*Manifest variables/key indicators*
Plan performance	P_1: Order entry method P_2: Order lead-time P_3: Customer order path
Source performance	S_1: Supplier selection S_2: Purchase order cycle time S_3: Buyer-supplier relationship S_4: Mutual assistance in solving problems
Manufacturing performance	M_1: Effectiveness of a master production schedule M_2: Capacity utilization M_3: Product cost M_4: Quality M_5: Flexibility M_6: Range of product and services
Delivery performance	D_1: Flexibility of delivery systems to meet particular customer needs D_2: Effectiveness of delivery invoice methods D_3: On time delivery of goods D_4: Delivery lead time
Customer service performance	CS_1: Flexibility to meet particular customer needs CS_2: Post transaction measures of customer service CS_3: Customer query time
Supply chain performance	SCP_1: Information carrying cost SCP_2: Manufacturing cost SCP_3: Flexibility of service system to meet customer needs SCP_4: Total inventory cost

The questionnaire developed here is divided into two parts. The first part consists of general questions related to the respondent's details like, age, experience, position, qualification, company's turnover, no. of employees etc. The second part includes the questions related to above discussed constructs, where the respondents were asked to indicate the degree to which they agree with the statement in a 7-point Likert scale and an example of a question is shown below.

Please rate your response in a scale of 1–7, where '1' = Extremely unimportant and '7' = Extremely important (see Appendix B).

Data were collected with the help of structured questionnaire by making personal visits to various companies and finally 226 responses were collected. The survey was conducted among the Indian automotive firms. Case companies situated in different parts of the India. Entire data were collected through off-line survey by face-to-face interview or personal visits. Details of the data collection methods have been described in research methodology chapter (see Chapter 6). Different approaches were used in order to maximize the response rate and to motivate the respondents. The respondents were guaranteed privacy of their data.

7.3.1 Non response and common method biases

Here, we analyzed the data for two kinds of biases namely (i) non-response bias, and (ii) common methods bias. The detail discussion and results for both biases are demonstrated in the next sub-sections.

7.3.1.1 Non response bias

To assess non-response bias in the data collected, statistical difference test between earliest and latest responses is applied (Armstrong and Overton, 1977; Krause and Scannel, 2002; Rahman and Siddiqui, 2006; Kureshi *et al.*, 2010). By this method, first 113 and last 113 respondents were checked and compared (Armstrong and Overton, 1977). This is validated by using T-test with 95 percent confidence level ($P \geq 0.05$) among these two groups with respect to overall SCP. Table 7.2 shows the results of paired sample T-test between early and late respondents and it is cleared that there is no significant difference between the early and late responses. Therefore, it is concluded that there was no evidence of non response bias in collected data and it may not be a problem in this study. SPSS 19.0 has been used in this study to calculate the F values and their significance level.

Table 7.2: Non-response bias test

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
P_1	Between Groups	0.071	1	0.071	0.093	0.761
	Within Groups	171.044	224	0.764		
	Total	171.115	225			
P_2	Between Groups	0.748	1	0.748	1.022	0.313
	Within Groups	163.912	224	0.732		
	Total	164.659	225			
P_3	Between Groups	0.535	1	0.535	0.591	0.443
	Within Groups	202.885	224	0.906		
	Total	203.420	225			
S_1	Between Groups	0.442	1	0.442	0.450	0.503
	Within Groups	220.124	224	0.983		
	Total	220.566	225			
S_2	Between Groups	0.004	1	0.004	0.004	0.948
	Within Groups	230.956	224	1.031		
	Total	230.960	225			
S_3	Between Groups	0.358	1	0.358	0.455	0.501
	Within Groups	176.460	224	0.788		
	Total	176.819	225			

S_4	Between Groups	0.442	1	0.442	0.487	0.486
	Within Groups	203.487	224	0.908		
	Total	203.929	225			
M_1	Between Groups	0.637	1	0.637	0.638	0.425
	Within Groups	223.628	224	0.998		
	Total	224.265	225			
M_2	Between Groups	0.000	1	0.000	0.000	1.000
	Within Groups	261.841	224	1.169		
	Total	261.841	225			
M_3	Between Groups	0.000	1	0.000	0.000	1.000
	Within Groups	211.611	224	0.945		
	Total	211.611	225			
M_4	Between Groups	0.159	1	0.159	0.173	0.678
	Within Groups	205.858	224	0.919		
	Total	206.018	225			
M_5	Between Groups	0.071	1	0.071	0.082	0.775
	Within Groups	194.053	224	0.866		
	Total	194.124	225			
M_6	Between Groups	0.004	1	0.004	0.006	0.941
	Within Groups	180.106	224	0.804		
	Total	180.111	225			
D_1	Between Groups	0.111	1	0.111	0.105	0.747
	Within Groups	236.938	224	1.058		
	Total	237.049	225			
D_2	Between Groups	0.217	1	0.217	0.212	0.646
	Within Groups	229.558	224	1.025		
	Total	229.774	225			
D_3	Between Groups	0.283	1	0.283	0.355	0.552
	Within Groups	178.708	224	0.798		
	Total	178.991	225			
D_4	Between Groups	0.071	1	0.071	0.077	0.782
	Within Groups	207.062	224	0.924		
	Total	207.133	225			
CS_1	Between Groups	0.283	1	0.283	0.261	0.610
	Within Groups	243.469	224	1.087		
	Total	243.752	225			
CS_2	Between Groups	0.159	1	0.159	0.185	0.668
	Within Groups	192.973	224	0.861		
	Total	193.133	225			
CS_3	Between Groups	0.111	1	0.111	0.133	0.716
	Within Groups	186.460	224	0.832		
	Total	186.571	225			
SCP_1	Between Groups	0.867	1	0.867	0.769	0.381

	Within Groups	252.496	224	1.127		
	Total	253.363	225			
SCP_2	Between Groups	0.442	1	0.442	0.480	0.489
	Within Groups	206.549	224	0.922		
	Total	206.991	225			
SCP_3	Between Groups	0.004	1	0.004	0.003	0.955
	Within Groups	310.991	224	1.388		
	Total	310.996	225			
SCP_4	Between Groups	0.637	1	0.637	0.495	0.482
	Within Groups	288.301	224	1.287		
	Total	288.938	225			

7.3.1.2 Common method bias

Common method bias is a normal concern for organizational researcher and deals with mixed result concerning the seriousness of the problem. There is a probability of common method biases in self-reported data resulting from multiple sources (Podsakoff *et al.*, 2003; Turker, 2009). Here, we performed statistical analyses to assess the presence of common method bias in our data. First, we performed Harmon's one-factor test on six latent variables/constructs in our theoretical model including plan performance, source performance, manufacturing performance, delivery performance, customer service performance, and supply chain performance. The test results show that the most covariance explained by one construct is 9.79 percent, which indicate that common method biases are not concerns in this study.

Further, following Podsakoff *et al.* (2003), a common method is included in the PLS model whose factors included all the principal constructs' factors and calculated each factor's variances substantively explained by the principal construct and by the method. The results present in the Table 7.3 reveal that the average substantively explained variance of the factors is 0.6340, while the average method based variance is 0.0307. The ratio of substantive variance to method variance is about 20:1. Moreover, most of the factor loadings of the manifest variables/indicators are not significant. Consequently, given the small magnitude and insignificance of method variance, we state that the method is unlikely to be a serious concern for this study.

Table 7.3: Common method bias analysis

Latent Variable	*Manifest Variable*	*Substantive Factor Loading (R_1)*	*R_1^2*	*T-value*	*P-value*	*Method Factor Loading (R_2)*	*R_2^2*	*T-value*	*P-value*
Plan performance	P1	0.8896	0.7914	7.3820	0.0001	-0.1709	0.0292	1.2752	0.2028
	P2	0.9257	0.8569	7.7143	0.0001	-0.1075	0.0116	0.9106	0.3630
	P3	0.8635	0.7456	4.7181	0.0001	0.2515	0.0633	1.8386	0.0666
Source performance	S1	0.9272	0.8597	18.0483	0.0001	-0.2694	0.0726	3.5689	0.0004
	S2	0.6728	0.4527	2.0725	0.0387	0.3342	0.1117	1.9191	0.0555
	S3	0.7050	0.4970	1.7367	0.0831	0.3686	0.1359	1.7889	0.0742
	S4	0.9599	0.9214	17.5996	0.0001	-0.2565	0.0658	3.1907	0.0015
Manufacturing performance	M1	0.7600	0.5776	3.9836	0.0001	-0.1081	0.0117	0.5559	0.5785
	M2	0.7229	0.5226	5.9918	0.0001	0.0445	0.0020	0.3383	0.7353
	M3	0.7519	0.5654	2.6564	0.0082	0.1793	0.0321	0.8880	0.3750
	M4	0.7478	0.5592	7.0930	0.0001	-0.0579	0.0033	0.3185	0.7502
	M5	0.8256	0.6816	5.0111	0.0001	-0.0200	0.0004	0.1271	0.8989
	M6	0.8280	0.6856	4.2438	0.0001	-0.0302	0.0009	0.1661	0.8681
Delivery performance	D1	0.6723	0.4520	5.0022	0.0001	-0.0405	0.0016	0.2024	0.8397
	D2	0.7461	0.5567	6.5639	0.0001	-0.0091	0.0001	0.0593	0.9527
	D3	0.8636	0.7458	2.9052	0.0038	-0.1266	0.0160	0.6860	0.4931
	D4	0.7678	0.5895	5.0022	0.0001	0.1764	0.0311	1.0379	0.2998
Customer service performance	CS1	0.7403	0.5480	4.0756	0.0001	0.2942	0.0866	1.9046	0.0574
	CS2	0.8974	0.8053	10.2007	0.0001	-0.1686	0.0284	1.7290	0.0844
	CS3	0.9135	0.8345	8.5842	0.0001	-0.1231	0.0152	0.9791	0.3280
Supply chain performance	SCP1	0.6563	0.4307	1.8322	0.0675	0.0904	0.0082	0.3278	0.7432
	SCP2	0.8147	0.6637	4.6923	0.0001	-0.0928	0.0086	0.4943	0.6213
	SCP3	0.6990	0.4886	4.7381	0.0001	0.0096	0.0001	0.0527	0.9580
	SCP4	0.6195	0.3838	2.9829	0.0030	0.0011	0.0000	0.0057	0.9954
Average		*0.7904*	*0.6340*			*0.0070*	*0.0307*		

7.3.2 Demographic profile of the respondents and companies

Demographic data provides the information about the characteristics of the respondents. The first section of data collection instrument is dedicated to demographic data of the respondents and companies, which includes certain questions related to various characteristics of the respondents and company.

7.3.2.1 Gender of respondents

Related to gender, there are 221 male (98 percent) and 5 female (2 percent) respondents in the collected data (see Figure 7.2). It suggests that the Indian automotive firms prefer more male candidates at various levels in their organization.

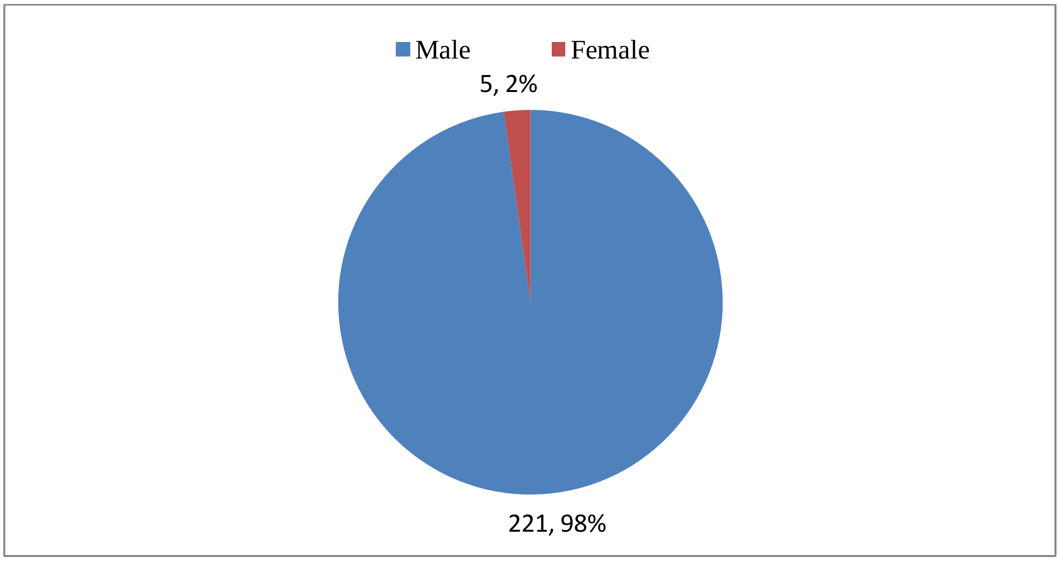

Figure 7.2: Gender of respondents

7.3.2.2 Qualification of respondents

With respect to the qualification of the respondents, the results indicate that 39 percent respondents are diploma holder, 38 percent are graduate/under-graduate, and remaining is postgraduate as shown in Figure 7.3.

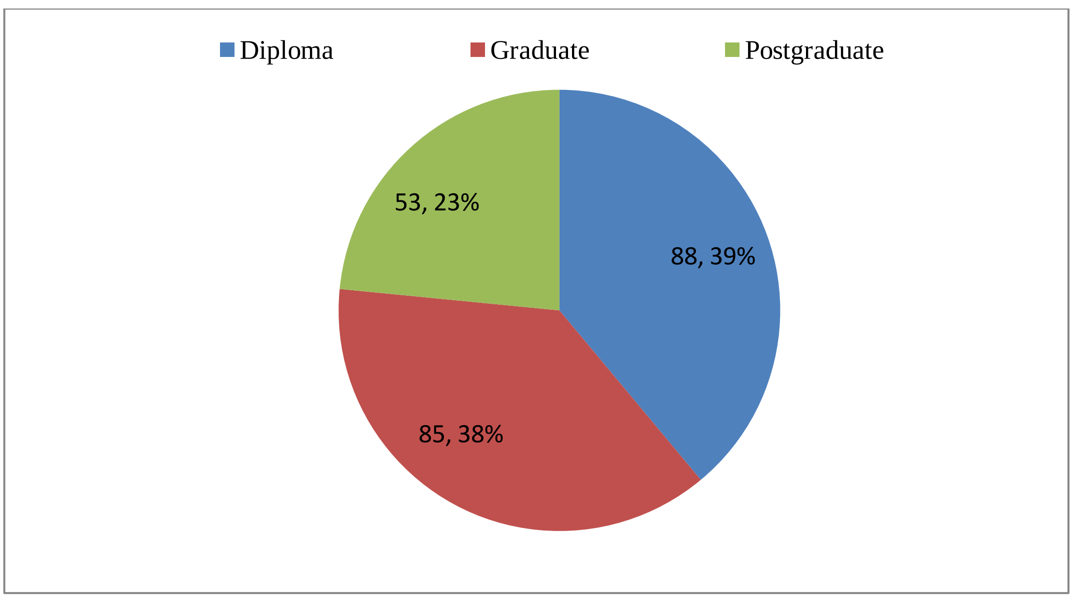

Figure 7.3: Qualification of respondents

7.3.2.3 Individual job function/position

This study was conducted on the basis of managerial perception of SCP in the Indian automotive firms. It is assumed that the top and middle level managers' perceived good information pertaining to each construct and their factors used in this study. Out of all respondents, 58 percent respondents held a position at middle level management, 28 percent at senior level management, and remaining 14 percent at lower level management as shown in Figure 7.4. This shows that collected data provide the desired information.

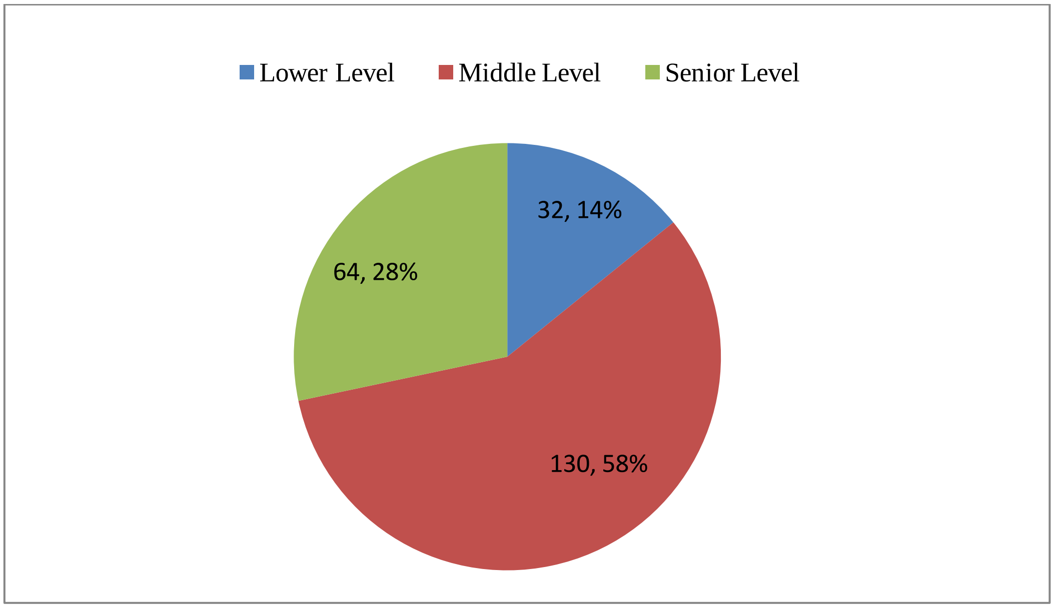

Figure 7.4: Job positions of respondents

7.3.2.4 Age of respondents

With regard to participant's age, 51 respondents (23 percent) were less than 25 years old, 57 respondents (25 percent) were less than 30 years old, 30 respondents (13 percent) were less than 35 years old, 26 respondents (12 percent) were less than 40 years old, and 62 respondents (27 percent) were more than 40 years old (see Figure 7.5). The results indicate that data are collected mostly from the seniors managers who are adequately aware about their firm's SC.

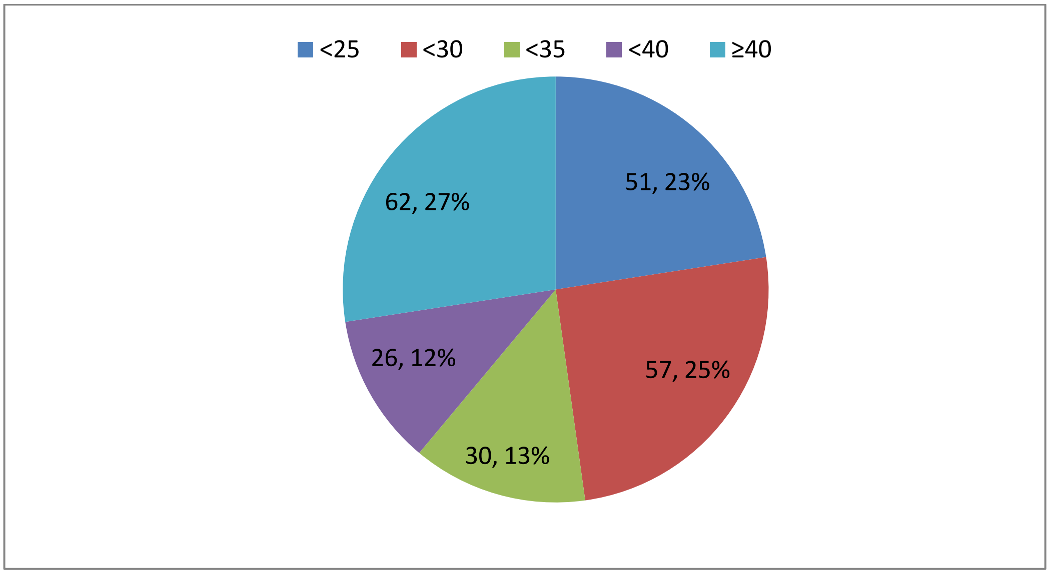

Figure 7.5: Age of respondents

7.3.2.5 Experience of respondents

Out of all respondents, 34 percent have an experience of less than five years, 21 percent have less than ten years' experience, 14 percent have less than fifteen years' experience, 10 percent have experience of less than twenty years, and 21 percent have more than twenty years' experience (see Figure 7.6).

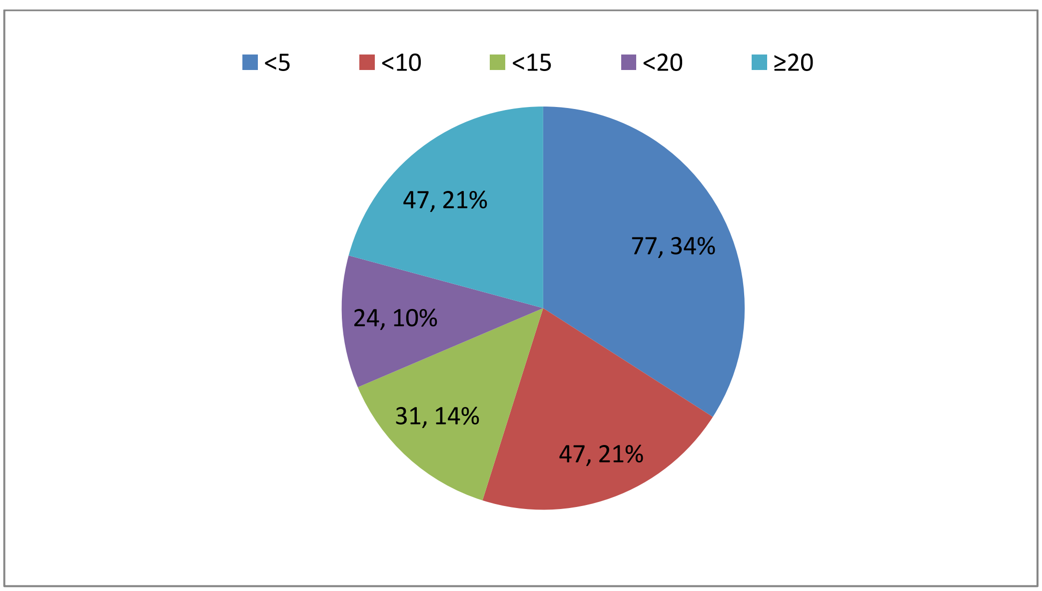

Figure 7.6: Years of experience

7.3.2.6 Number of employees

With respect to number of employees, the results depict that 32 percent of the total companies have less than 100 employees, 16 percent companies have less than 200 employees, 23 percent companies have less than 500 employees, 12 percent companies have less than 1000 employees, and 17 percent have more than 1000 employees as shown in Figure 7.7.

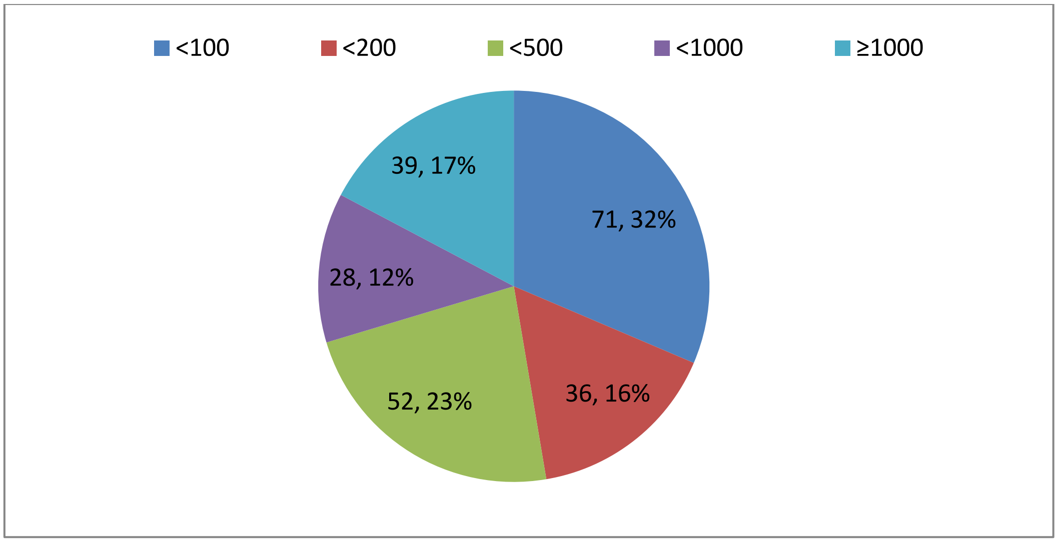

Figure 7.7: No. of employees

7.3.2.7 Companies turnover

Out of all consulted automotive firms, 28 percent companies' turnover is between 1-10 crores, 9 percent companies have 10-20 crores turnover, 4 percent have 20-30 crores, 6 percent have 30-40 crores, while more than 50 percent companies have more than 40 crores turnover (see Figure 7.8).

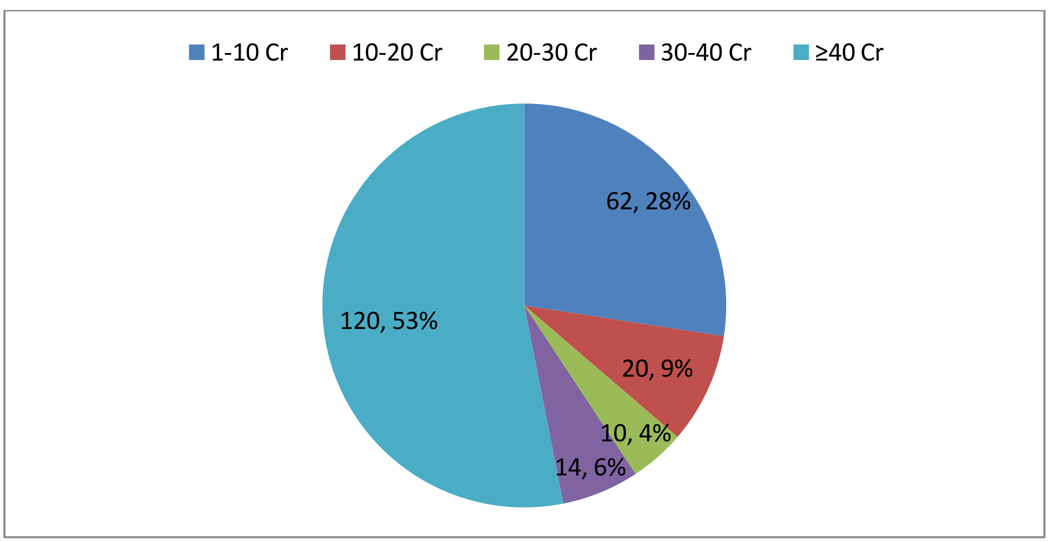

Figure 7.8: Companies turnover

7.3.3 Scale development

In this study, a scale is developed following the steps of Churchill (1979). Various authors have further modified these steps (e.g. Bentler and Bonnet, 1980; Bagozzi *et al.*, 1991; Nunnally and Bernstein, 1994; Turker, 2009; Pullman *et al.*, 2010). The scale development stages are discussed in next section.

7.3.3.1 Item generation and selection

To generate the latent variables or constructs and their factors, an extensive literature review was conducted and then total 73 factors/indicators were detailed as follows: plan performance (15 items), source performance (14 items), manufacturing performance (20 items), delivery performance (14 items), customer service performance (6 items), and overall supply chain performance (4 items). After collection of these factors, an initial screening was done.

Next, different panels of experts (Managers/Academicians) were invited to examine the 73 factors and asked to keep only the significant items related to SCPM. Following Lin and Hsieh (2011), the experts were called to assign the factors to one of the three categories i.e., “not representative”, “somewhat representative” or “clearly representative”. The items rated “somewhat representative” or “clearly representative” by at least 80 percent of the experts were retained. Consequently, the experts’ deleted 49 out of 73 factors/indicators as these factors were unclear and vague or reflect the same information. Finally, a questionnaire was prepared with remaining 24 factors. The next section deals with validity and reliability of the scale.

7.3.3.2 Unidimensionality check of the blocks

Initially, the unidimensionality of each construct was measured for the proposed model. This test is required when the manifest variables are connected to their constructs or latent variables in a reflective way (Tenenhaus *et al.*, 2005). It can be checked in different approaches such as principal component analysis of the block, Cronbach’s α and Dillon-Goldstein’s α. If first eigenvalue of the correlation matrix of a block manifest variable is larger than one and the other eigenvalue is smaller than one then block is unidimensional. Similarly, if the values of Cronbach’s α and Dillon-Goldstein’s α are greater than 0.7 then also block is considered unidimensional (Tenenhaus *et al.*, 2005). The results presented in Table 7.4 show that the values of both Cronbach’s α and Dillon-Goldstein’s α are greater than 0.7. Moreover, the first eigenvalue of each block is larger than 1 and second eigenvalue is less than 1. Thus, the unidimensionality of all blocks is acceptable.

Table 7.4: Unidimensionality check of the blocks

SCPM constructs	*No. of key factors/indicators*	*Cronbach's alpha*	*Dillon-Goldstein alpha*	*First eigenvalue*	*Second eigenvalue*
Plan performance	3	0.7085	0.8352	1.895	0.578
Source performance	4	0.7930	0.8680	2.523	0.772
Manufacturing performance	6	0.8415	0.8832	3.350	0.641
Delivery performance	4	0.7186	0.8248	2.171	0.685
Customer service performance	3	0.7370	0.8470	1.969	0.609
Supply chain performance	4	0.7398	0.8372	2.255	0.672

7.4 Measurement model and results

The measurement model presents the relationships between each block of factors/indicators and their latent variable or construct. Partial least square (PLS) approach was used to measure the reliability of each item by measuring the loading of manifest variables with their respective latent variable. SmartPLS, Version 2.0 M3 an open-source software package is used for the analysis (Ringle *et al.*, 2005). The sample size of 226 is sufficient for using PLS technique (Chin and Newstead, 1995). The results of measurement model are presented in Table 7.5. Similar to erstwhile researchers, we also used the rule of thumb to accept the factors/indicators with loadings of 0.70 or greater than 0.70 and found that only three (S_3, M_4 and D_1) out of 24 indicators did not reach the level of acceptable reliability. However, Barclay *et al.* (1995) and Tenenhaus *et al.* (2005) have suggested that factors with loading of at least 0.5 are also acceptable.

7.4.1 Internal consistency

Fornell and Cha (1994) revealed that communality measures the capacity of the manifest variable to measure the related latent variable. Afthanorhan (2013) suggested that the value of communality might be accepted when it is greater than 0.50. The results presented Table 7.5 reveal that for all factors the value of communality is more than 0.50. Further, the Cronbach's α as well as composite reliability (CR) are the factors for construct reliability and values of these factors should be more than 0.7 (Nunnally, 1978' Fornell and Larcker, 1981; Gotz *et al.*, 2010). Table 7.5 depicts that for all constructs; the values of Cronbach's α and composite reliability are more than 0.7. Therefore, the construct reliability is not a concern in this study.

7.4.2 Convergent validity

The convergent validity of a construct can be examined by its average variance extracted (AVE) (Fornell and Larcker, 1981). AVE is the average value of the squared loadings of each factor/indicator on a construct and it gives an idea of how well a theoretical latent construct explains the variance of a set of factors/indicators that are supposed to measure that particular construct. A construct's AVE should be more than 0.5 (Fornell and Larcker, 1981; Fornell, 1992; Gotz *et al.*, 2010). The results in Table 7.5 demonstrate that AVE of all constructs or latent variables is more than the recommended 0.5 which signifies convergent validity of the model.

Table 7.5: Outer model results

Latent variable	*Manifest variable*	*Outer weight*	*Loadings*	*Communality*	*AVE*	*CR*	*Cronbach's alpha*
Plan performance	P_1	0.3459	0.7438	0.6289	0.6289	0.8352	0.7085
	P_2	0.3958	0.7806				
	P_3	0.5097	0.8510				
Source performance	S_1	0.3041	0.8767	0.6249	0.6249	0.8680	0.7930
	S_2	0.3381	0.7205				
	S_3	0.3196	0.6719				
	S_4	0.3154	0.8721				
Manufacturing performance	M_1	0.2237	0.7541	0.5579	0.5579	0.8832	0.8415
	M_2	0.2574	0.7883				
	M_3	0.2249	0.7326				
	M_4	0.1821	0.6987				
	M_5	0.2304	0.7659				
	M_6	0.2164	0.7389				
Delivery performance	D_1	0.2651	0.6577	0.5416	0.5416	0.8248	0.7186
	D_2	0.3540	0.7568				
	D_3	0.3592	0.7698				
	D_4	0.3729	0.7542				
Customer service performance	CS_1	0.5184	0.8311	0.6488	0.6488	0.8470	0.7370
	CS_2	0.3472	0.7881				
	CS_3	0.3709	0.7966				
Supply chain performance	SCP_1	0.3198	0.7012	0.5637	0.5637	0.8372	0.7398
	SCP_2	0.3370	0.7756				
	SCP_3	0.3615	0.8187				
	SCP_4	0.3116	0.7010				

7.4.3 Discriminant validity

Discriminant validity specifies the extent to which a given construct is different from all other latent variables in the same measurement model (Hulland, 1999; Gotz *et al.*, 2010). Discriminant validity of the measurement model can be estimated by comparing the values with square root of the AVE in diagonal with the correlations among reflective constructs. Fornell and Larcker (1981) suggested utilizing AVE to evaluate the discriminant validity of a scale. For this purpose, square root value of the AVE for each construct should be greater than the inter correlations with the other construct of the measurement model (Chin, 1998b). This comparison is presented in the Table 7.6 and the results shows that all constructs are more strongly correlated with their own measures compared to other constructs' factors/indicators. It shows that overall model qualifies the required conditions of discriminant validity and measurement model is reliable and valid.

Table 7.6: Correlation between latent variables

Latent variables	*PP*	*SP*	*MP*	*DP*	*CSP*	*SCP*
PP	**0.7930**	0	0	0	0	0
SP	0.5806	**0.7905**	0	0	0	0
MP	0.6135	0.5980	**0.7470**	0	0	0
DP	0.6022	0.6413	0.5737	**0.7360**	0	0
CSP	0.6546	0.5535	0.5479	0.6065	**0.8055**	0
SCP	0.7472	0.6901	0.7438	0.7109	0.6793	**0.7508**

Diagonal elements in the correlation matrix of latent variables shows the square root of the AVE

7.5 Structural model

Measurement model deals with relationship between latent variable and its items. The coefficient of determination (R^2) and significance level are the two criteria for evaluating the structural model in PLS (Chin, 1998b). Falk and Miller (1992) stated that the value of R^2 should be greater than 0.1. The results of the structural model are presented in Figure 7.9. In our model, the value of R^2 is 0.761 which means 76.1 percent SCP variance is explained by the proposed constructs. The high value of R^2 suggests that variance explained is high.

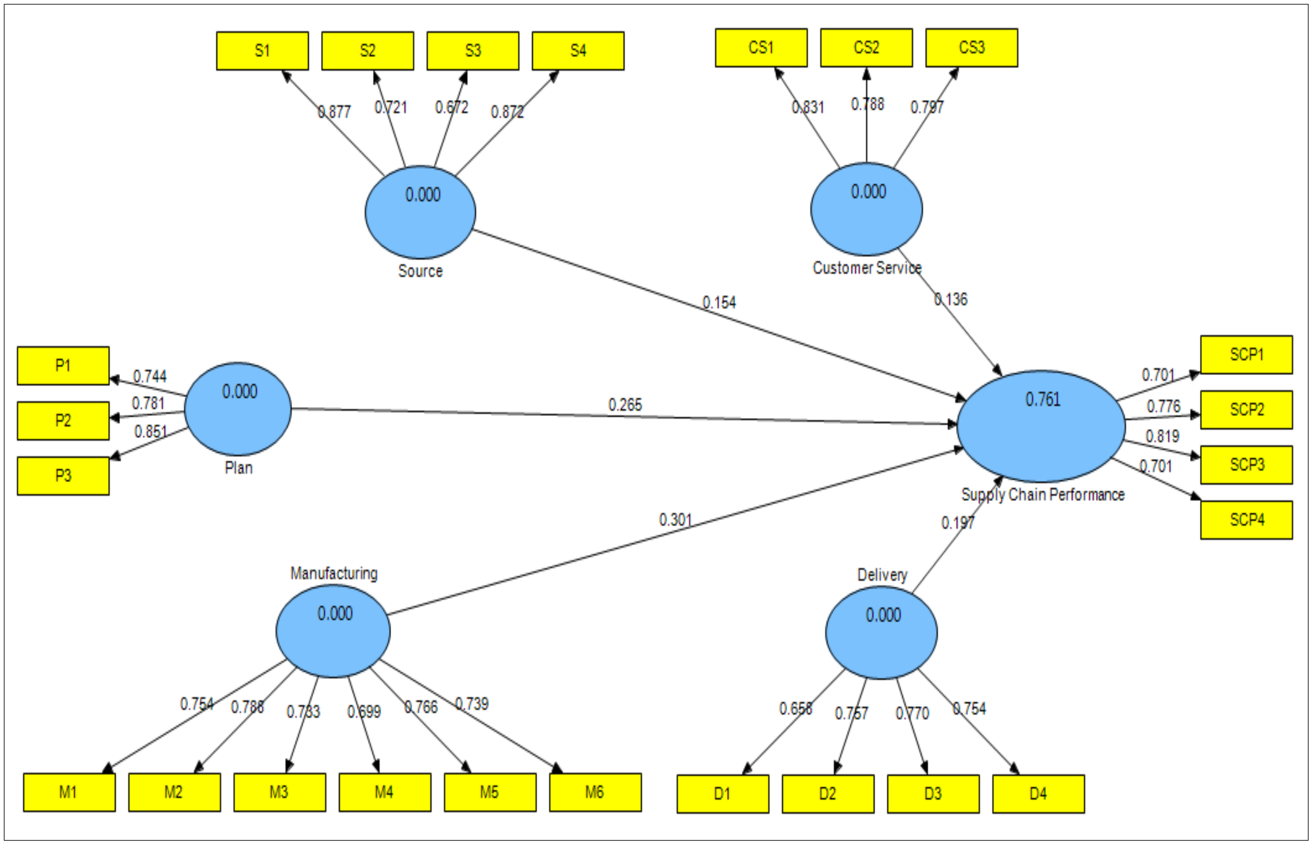

Figure 7.9: Results of structural model

7.5.1 Goodness of fit

Goodness-of-fit (GoF) indices reflect the predictive power of inner and outer model relationship (Sanchez-Hernandez and Miranda, 2011). The GoF measure assesses the overall model fit which can be expresses mathematically by

$$GoF = \sqrt{\overline{Communality} * \overline{R^2}}$$

Where, $\overline{Communality}$ = weighted average of different communality (=AVE in PLS) with number of factors/indicators as weight, and $\overline{R^2}$ = average of R^2 values of all endogenous constructs (Tenenhaus *et al.*, 2005; Akter *et al.*, 2011). The value of GoF varies from 0 to 1, where greater value indicates better predictive ability. In our case, the value of GoF was calculated as 0.6725, which indicates a substantial model fit. The structural model is tested by examining path coefficient and their significance levels in PLS. In order to obtain t-statistic values for examining the statistical significance of path coefficients, the bootstrapping technique with 500 random samples was performed. The results of hypotheses with path coefficient and respective significance levels are shown in subsequent section.

7.5.2 Hypotheses testing

The basic objective of path analysis is to provide a statistical tool to test and confirm the structural model to assess the hypotheses that represents the link among variables of interests (Kline, 2005). This is an important tool to assess the linkage among the variables because the main goal of path analysis is to make an approximation of the degree of association among the variables (Asher, 1983). The path analysis measures the relative importance of different direct and indirect causal paths leading to the dependent variable.

Hypothesis testing among the latent variables or constructs of various parameters qualifies various characteristics like quality, capability to explain the data, parallel to the perfection and prospects to explain the relationship (Lohmoller, 1989). These parameters include R^2 and path coefficients (Fornell and Cha, 1994) and these values provide proof of relationship existence among the constructs (Falk and Milller, 1992). According to Falk and Miller (1992), R^2 should be higher than 0.10 to show proof of relationship. In this study, the value of R^2 is higher than the standard level, which is suitable to evaluate the path significance. The structural model was tested by path cofficient and their significance levels in PLS. In PLS, bootstrapping technique was employed with 500 random samples to obtain the value of T-statistics, which we used to confirm the statistical significance of various paths presented in the structural model. The PLS bootstrapping results are shown in Table 7.7.

The path between plan performance and firm's overall SCP is statistically significant ($t=4.412$, $p=0.0001<0.05$) and fully supports hypothesis H_1 (Table 7.7 and Figure 7.10). The path between source performance and firm's overall SCP also found statistically significant ($t=3.043$, $p=0.0025<0.05$), proving the hypothesis H_2. The path between manufacturing performance and firm's overall SCP found statistically significant ($t=6.035$, $p=0.0001<0.05$) and supporting hypothesis H_3. The path between delivery performance and firm's overall SCP is also statistically significant and advocating hypothesis H_4 ($t=2.926$, $p=0.0036<0.05$). Finally, the path between customer service performance and firm's overall SCP is statistically significant ($t=2.603$, $p=0.0095<0.05$) and proving the hypothesis H_5.

These results are in the line of the studies by Benito and Benito (2005) and Rettab *et al.* (2009). Therefore we conclude that all hypotheses H_1-H_5 have positive impact on overall SCP in the Indian automotive industry.

Table 7.7: Results of hypothesis testing based on PLS analysis

Hypotheses	*Path*	*Path coefficient*	*T-statistics*	*P-value*	*Decision*
H_1	Plan → SCP	0.2651	4.412	0.0001	Supported
H_2	Source → SCP	0.1544	3.043	0.0025	Supported
H_3	Manufacturing → SCP	0.3014	6.035	0.0001	Supported
H_4	Delivery → SCP	0.1970	2.926	0.0036	Supported
H_5	Customer service → SCP	0.1356	2.603	0.0095	Supported

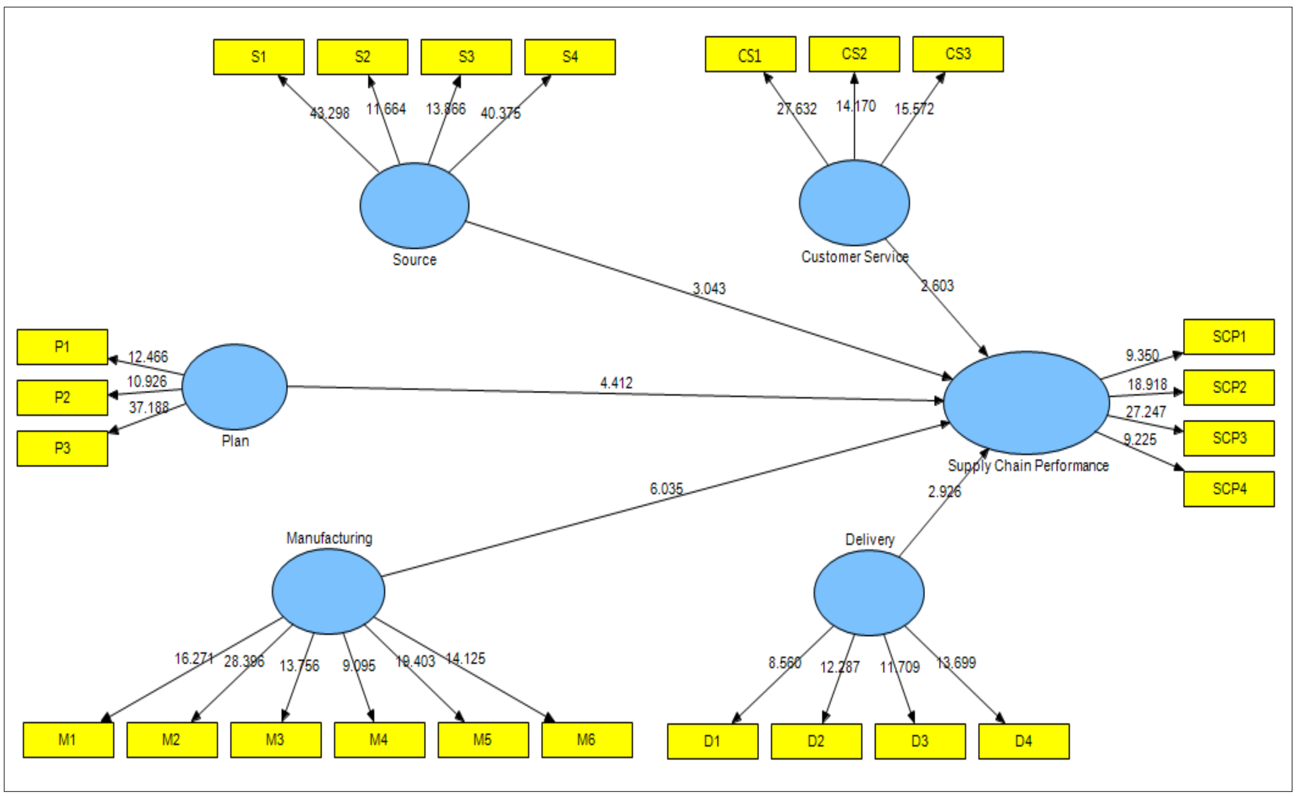

Figure 7.10: Results of T-statistics

7.6 Results and managerial implications

The main objective of this study was to first identify different constructs that affect SCP and then based on these constructs a scale was developed to measure SCP in the Indian automotive industry. Further, we explored the relationships of the identified constructs with overall SCP. The scale developed here is helpful for automotive organizations to measure the overall SCP of their firm.

Five constructs (i.e., plan performance, source performance, manufacturing performance, delivery performance, and customer service performance) were identified to measure overall SCP.

This study worked as an extension of belief that plan, source, manufacturing, delivery, and customer service performance have positive impact on SCP in developing countries. It extends theoretical support to the existing literature, which claims a positive relationship between variables of interest. Plan performance construct has three factors/indicators or manifest variables (i.e. order entry method, order lead time, customer order path). Similarly, other constructs also have different factors/indicators as discussed in Table 7.1. All factors were evaluated on the perception of 226 managers working in the case companies. The various constructs of SCP have shown high composite reliability (CR), which indicate that the constructs and factors/indicators that are used in this study are valid and automotive industries need to focus on these constructs and their factors to improve their SCP.

This study contributes to the existing theory by developing a scale and model for measuring SCP in the Indian automotive industry. Consistent with the prior studies, our results also indicate positive relationships of plan performance, source performance, manufacturing performance, delivery performance, and customer service performance with overall SCP. Another important contribution of this study is PLS path model that can be used to evaluate a hierarchical model containing a multi-order construct. Since PLS is believed to be suitable for understanding the complex relationship (Fornell and Bookstein, 1982). The path coefficient reveals that manufacturing performance is the most important construct to measure overall SCP as its path coefficient is highest (β=0.3014) and has positive impact on SCP. Further, the loading of the manifest variable of manufacturing performance depicts that all activities are nearly equally important, but the Indian automotive firms should give more emphasis on capacity utilization and flexibility in product manufacturing as their loadings are higher (i.e., 0.78 and 0.76 respectively) compared to other activities. The second most important construct is plan performance and it also positively affects SCP. The next important factors are delivery performance, source performance, and customer service performance that also have positive impact on SCP.

Erstwhile studies have not empirically evaluated about the relationship of SCP factors with firm's overall SCP. Therefore, this study offers a better in-depth contemporary understanding of these relationships in the context SCP improvement. This study also extends the theoretical contribution by employing the research model to a new setting that is the factors of firm's overall SCP model in the context of developing countries. According to Whetten (1989), "the common element in advancing theory development by applying it in new settings….that is, new applications should improve the tool, not merely repeat its utility".

Although this study focuses on theoretical reconceptualization and validation, the findings of this study have implication for practitioners as well. The empirical evidence of positive relationships of plan, source, manufacturing, delivery, and customer service with overall SCP will help mangers to improve in their firm's overall SCP. Further, any automotive firm can use the scale developed here to measure overall SCP. Consequently, improvement and gaps can be traced by assessing score on every factor/indicator, which may be helpful for firms to increase their overall SCP. Furthermore, managers can also use this scale for comparative analysis with past performance by developing data for the longitudinal studies.

7.7 Conclusion

In this chapter, a measurement model has been developed to deal with the research issue of SCP. To serve this purpose, a psychometric scale development process has been followed. The contributions of this chapter to the existing literature are in manifolds: first, it identifies the various constructs that affect the firm's SCP and based on these constructs a scale is developed for measuring the overall SCP. Second, we explored the relationships of different identified constructs with the firm's overall SCP. Five constructs such as plan performance, source performance, manufacturing performance, delivery performance, and customer service performance are identified that affect SCP. The reliability and validity of these constructs were checked by PLS approach. Based on these constructs, five hypotheses were constructed. We used SmartPLS 2.0 M3 software to test the hypotheses. This chapter studies SCPM only from the buyers' perspectives and this is one of the limitations of this study. Consequently, for more generalized findings, study should be made considering suppliers and buyers together of different organizations. Further, the sample size used in this study is relatively small and therefore, one can study the similar problem by collecting more data and also same problem can be studied in industries.

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CHAPTER 8
Summary, Conclusions, Implications, and Scope for Future Work

Preview

This chapter provides an overview of the research work conducted in the present study by discussing major research outcomes and key results. The implications of the present study are also provided. The implications of this study will to ensure its use by both academicians and practitioners. Finally, the limitations and scope for future research are also suggested.

8.1 Introduction

In today's business environment and this competitive scenario the outcome of the companies' decision is under close scrutiny. The demand for information and progress towards organizations performance is increasing among stakeholders. Companies are trying to measure and improve their supply chain performance through various activities. Although, industries are performing well in their supply chain but there is need to know about the key factors and barriers of supply chain performance measurement. Therefore, it is necessary to measure the supply chain performance and its impact on a company's bottom line. Nowadays, the changing market scenario in the Indian automotive sector demands more research in the field of performance measurement. The proposed research work first focuses on exploring the interrelationships for significant factors and barriers of supply chain performance measurement. Second, it explicitly focuses on developing an integrated fuzzy AHP based model for supplier selection under multiple criteria settings. At last, this work focuses on developing a scale to measure the overall supply chain performance in the Indian automotive industry. This study works as a path for both researchers and practitioners working in this field of study. This study will help in decision making by measuring the impact of supply chain performance measurement constructs and their key factors on firm's overall supply chain performance.

8.2 Summay and contributions

In this section research summary and contributions of each chapter are discussed.

Chapter 1: This chapter provides the brief introduction of supply chain performance measurement, problem statement, motivation for the present research and also discusses the research objectives of the study.

Chapter 2: This chapter presents the detailed review of relevant literature. In the initial part of this chapter, a brief introduction of the Indian automotive sector is given. After that, we discuss the erstwhile literature pertaining to supply chain management, supply chain performance measurement with their some definitions. In the section of supply chain performance measurement, we identify SCPM constructs/attributes, key factors/sub-attributes, and barriers of the Indian automotive supply chain. Further, the literature review is classified into several categories like; country-wise, industry-wise, and journal-wise. Finally, this chapter shows the various gaps in the literature, which resulted in the objectives of this research.

Chapter 3: This chapter explores the interrelationships among the key factors of supply chain performance measurement in the the Indian automotive industry. Key factors used in this study are crucial to measure SCP of the firm. These factors are essential in terms of policy making and improving the supply chain performance. In this chapter, an interpretive structural modeling (ISM) with a fuzzy MICMAC based approach is used to examine the interactions among the key factors. This chapter describes the most leading twenty key factors and explores the interrelationships among them. These key factors are identified based on literature review and a brainstorming session. The purpose of the brainstorming session was to identify the key factors of SCPM and developing a relationship matrix as a first step towards building the ISM-based model. In the beginning, the relationships among the key factors are explored using the ISM approach. Such relationships among the key factors can help a firm's top management to make essential judgments in order to solve the overall supply chain problems and provide a better approach to proactively deal with problems. In addition, these key factors are helpful in measuring the SCP of the Indian automotive firms. Further, the driving power and dependency power are calculated using fuzzy MICMAC analysis. This analysis provides valuable suggestions for the top management of automotive firms about the significance of the key factors.

The results show that the order entry method (OEM) and order lead time (OLT) are significant key factors, showing a higher driving power and at the bottom of the ISM-based hierarchy model. Therefore, top management must focus on these key factors to make an effective and efficient SC. These results may useful for the firm's management in order to rethink their business strategy. From fuzzy MICMAC analysis, it is seen that there is no autonomous key factor, which suggests that all the considered key factors influence supply chain performance in the Indian automotive industry. It is also observed that customer query time (CQT), post-transaction measure of customer service (PTMCS), flexibility to meet particular customer needs (FMPCN), delivery lead time (DLT), on-time delivery of goods (OTDG), effectiveness of delivery invoice methods (EDIM), and flexibility of the delivery systems to meet particular customer needs (FDSMPCN) are weak key factors. Only seven key factors are weak drivers and are more dependent on others. However, they have a strong dependence on other key factors such as the order entry method (OEM), order lead time (OLT), customer order path (COP), supplier selection (SS), purchase order cycle time (POCT), buyer-supplier relationship (BSR), mutual assistance in solving problems (MASP), effectiveness of master production schedule (EMPS), and capacity utilization (CU). Nine key factors have the least amount of dependence but a strong driving power. Thus, these are root key factors and management should focus on these key factors as an initiative to improve their SCP. These key factors represent the awareness related to SCPM with a high support of buyer's strategy or industry's planning performance as well as supplier's involvement. This study also observes that there are four linkage key factors i.e., product cost (PC), quality (Q), flexibility (F), and range of product and services (RPS). These connect the driving key factors with the dependent key factors. The linkage key factors are derived from the absolute driving key factors and are the result of absolute dependent key factors.

Chapter 4: This chapter explores the interactions among the barriers of SCPM in the Indian automotive industry. These barriers are essential and pose considerable challenges for the policy makers and managers to measure SCP. The Indian automotive industries are facing several issues in SCPM due various constraints. These constrains act like a barrier of SCPM. This chapter first identifies fourteen barriers based on literature review and experts' opinion. Second, brainstorming sessions were conducted with sixteen experts to develop a relationship matrix among the barriers and then developed a hierarchy model using an ISM approach. The barriers identified in this study helps to measure the SCP of Indian automotive firms and that is helpful for companies to become more successful and efficient. This chapter also uses fuzzy MICMAC approach with an interpretive structural modeling. The fuzzy MICMAC analysis presents the driving power and dependency power of four clusters with the help of fuzzy numbers. Results provide valuable suggestions to the top managers of automotive firms about impact of the identified barriers. The results indicate that the lack of awareness related to SCP measurement system (Barrier 1) is one of the major barrier, and indicationsa higher driving power at the bottom level of the hierarchy. Therefore, the top management should put more focus on this barrier to build effective and efficient supply chain.

There are no autonomous barriers for this study and all considered barriers influence the SCP in the Indian automotive organizations. It is also observed that the encroaching market competition and uncertainty in demand (Barrier 8), disinclination of the support from distributors, retailers and dealers (Barrier 5), lack of trained manpower (Barrier 4), dispersed IT infrastructure (Barrier 12), inefficient information and technology system (Barrier 6), lack of consistency in business capability between buyers and suppliers (Barrier 11), lack of appropriate implementation of SCP measurement system (Barrier 7), and lack of appropriate production technology adoption (Barrier 9) are the weak driving barriers. However, these barriers have a strong dependence on other barriers such as lack of support from government systems (Barrier 10), lack of funding or financial constraints (Barrier 13), lack of top management dedication (Barrier 3), destitute quality of human resource (Barrier 14), and lack of awareness related to SCP measurement systems (Barrier 1). There is only one linkage barrier i.e., inadequate strategic planning (Barrier 2) which connects the driving barriers with dependent barriers. The linkage barriers are derived from the absolute driving barrier and results in an absolute dependent barrier. Only five barriers have a strong driving power and are less dependent on others. Therefore, these are the root barriers and a firms' top management must give more attention to these barriers in order to become successful. These findings may help the top management in identifying the barriers that affect SCP improvement.

Chapter 5: This chapter develops an integrated fuzzy AHP based model for supplier selection under multiple criteria settings. An initial hierarchy based model is developed based on the five attributes (such as plan, source, manufacturing, delivery, and customer service), twenty sub-attributes, and three alternatives (suppliers). To illustrate the proposed model a group of three suppliers is considered. Here, attributes and sub-attributes are identified based on literature review and experts' opinion that affect firm's SCP. In brainstorming session, experts' were asked to prioritize the attributes and sub-attributes using fuzzy scale. Thus, a fuzzy pair-wise comparison matrix with respect to the goal is made. Similarly, other pair-wise comparison matrices are finalized with respect to the attributes and sub-attributes with the help of experts' opinion. The experts were asked to compare the suppliers against each SCP sub-attribute. Finally, suppliers were raked based on the overall weightage. The raking results show that supplier 1 is the best supplier in terms of attributes and sub-attributes compared to other two suppliers. This chapter explains that plan attribute is the most important among all attributes with weight of 0.33 followed by manufacturing (0.28), and customer service (0.27), source (0.11), and delivery (0.02). These results show that there will be considerable improvement in SCP, if the firm focuses well on planning, manufacturing, and customer service attributes. This chapter also provides information about the most appropriate supplier for improving the overall SCP. From the results, it is found that the weight of supplier 1 is the highest weight (0.4234) among all three suppliers. Therefore, supplier 1 is selected based on alternative priority weight and performance. The weight of supplier 2 and supplier 3 are 0.4069 and 0.1695 respectively. Furthermore, managers have the freedom to include the customized SCP attributes and sub-attributes based on the type of industries and specific problems under consideration. Thus, proposed hierarchy model can also be used to review current supplier selection problem. Finally, this study helps to decision makers in reducing a base of potential suppliers to a manageable number and make the supplier selection by means of multi-criteria techniques.

Chapter 6: This chapter accomplishes the fourth objective of this thesis which is based on developing a scale for measuring the supply chain performance in the Indian automotive industry. This chapter describes the outlay of the scale development process to validate the already proposed model in Chapter 2. Further, this chapter discusses in brief about the scalling techniques, research design, questionnaire design, sampling desing, data collection and analysis procedures. A detailed description of the data analysis process is given in the subsequent Chapter 7 of the present study.

Chapter 7: This chapter identifies the various constructs that affect the firm's overall SCP and based on these constructs a scale is developed for measuring SCP in the Indian automotive industry. First, this study identifies different constructs that affect SCP, second explores the relationships of different identified constructs with overall SCP. The scale developed here is helpful for automotive companies to measure the overall SCP of their firm. A scale development process was pursued at the different stages. Five constructs (i.e., plan performance, source performance, manufacturing performance, delivery performance, and customer service performance) were identified to measure overall SCP. Outcome of this study presents a good overview of various SCPM constructs and their key factors. Moreover, this study will also help the managers to improve and make efficient their firm's supply chain performance. This study worked as an extension of belief that plan, source, manufacturing, delivery, and customer service performance have positive impact on SCP in developing countries. It extends theoretical support to the existing literature, which claims a positive relationship between variables of interest. Plan performance construct has three factors/indicators or manifest variables (i.e. order entry method, order lead time, customer order path). Similarly, other constructs also have different factors or indicators. All factors were evaluated on the perception of 226 managers working in the case companies. The various constructs of SCP have shown high composite reliability (CR), which indicate that the constructs and key factors that are used in this study are valid and automotive industries need to focus on these constructs and their key factors to improve their SCP.

The reliability and validity of these constructs were checked by PLS approach. Based on these constructs, five hypotheses were constructed. We used SmartPLS 2.0 M3 software to test the hypotheses. Another important contribution of this study is PLS path model that can be used to evaluate a hierarchical model containing a multi-order construct. Since PLS is believed to be suitable for understanding the complex relationship. The path coefficient reveals that manufacturing performance is the most important construct to measure overall SCP as its path coefficient is highest (β=0.3014) and has positive impact on SCP. Further, the loading of the manifest variable of manufacturing performance depicts that all activities are nearly equally important, but the Indian automotive firms should give more emphasis on capacity utilization and flexibility in product manufacturing as their loadings are higher (i.e., 0.78 and 0.76 respectively) compared to other activities. The second most important construct is plan performance and it also positively affects SCP. The next important factors are delivery performance, source performance, and customer service performance that also have positive impact on SCP.

Earlier studies have not empirically evaluated about the relationship of SCP factors with firm's overall SCP. Therefore, this study offers a better in-depth contemporary understanding of these relationships in the context SCP improvement. This study also extends the theoretical contribution by employing the research model to a new setting that is the factors of firm's overall SCP model in the context of developing countries. Although this study focuses on theoretical reconceptualization and validation, the findings of this study have implication for practitioners as well. The empirical evidence of positive relationships of plan, source, manufacturing, delivery, and customer service with overall SCP will help mangers to improve in their firm's overall SCP. Further, any automotive firm can use the scale developed here to measure overall SCP.

8.3 Implications of the present study

The outcomes of the present research add to the existing body of literature on supply chain performance/performance measurement. The results of the study provide a path for both academicians and practitioners for the measurement and improvement of supply chain performance in the long run as well its impact on a firm's outcome. The main possible implications of the present research are:

- A bibliographic record provided in the literature review may work as a guideline for future research in this field of study.
- Advantages and disadvantages of qualitative and quantitative techniques may work as a source of learning in the selection of an appropriate technique by the researcher.
- The scale development process may be useful for academicians/researchers to develop a scale in different areas of interest.
- This study is for the automotive sector. So the developed scale in the present study can be used with some modifications for any other specific industries.
- Identified key factors related to supply chain performance measurement may be helpful for a further study in this field. This study presents the practical implications of the identified constructs and their key factors. Their application in the Indian automotive sector provides a guideline for the managers and decision makers to improve their supply chain performance.
- The outcome of the study provides a sound rationalization for the use of the different techniques applied for the measurement of supply chain performance. The results of the study are the outcome of both the quality of the process and the techniques adopted in the present research.

- Managers or decision makers of automotive industries may adopt a technique like ISM for selecting driving key factors of supply chain performance measurement. Similar technique may be used to study the critical barriers in the Indian automotive supply chain.
- The alternative priority weight of SCPM attributes, sub-attributes, and suppliers may be helpful for the decision makers in the improvement of supply chain performance and selection of appropriate supplier by ensuring proper resource allocation especially in the situation of limited suppliers. Therefore, top management of the industry may adopt fuzzy AHP technique for the ranking of attributes and sub-attributes for their specific set of requirements.
- Finally, the model developed here shows a positive impact of plan, source, manufacturing, delivery, and customer service performance on overall supply chain performance. These results may work as motivating factors to measure towards supply chain performance and to improve the performance of the organization.

8.4 Limitations of the study

Every study has its own limitation due to various factors. This limitation may be time, sample, availability of data, and research techniques etc. These limitations may provide various useful inputs that can be addressed in future studies. The limitations of the present study are as follows:

- The ISM-based model developed here is limited to identification of key factors and barriers of SCPM in the Indian automotive industry based on literature review and experts' opinion. This may be lead to some biasedness in the comparative analysis and may result in a significant difference in the relative importance of the key factors and barriers as well. However, there is always a possibility of biasness and transitivity.
- The key factors and barriers considered here may be partial or their relationships may be different according to the types and sizes of the firm.
- In the fuzzy AHP approach, the model was also developed by using experts' opinion. This technique may also be lead to some biasedness in the comparative analysis of various attributes and may result in a significant difference in the relative weights of the attributes and sub-attributes.
- The scale developed in the study is an industry specific for automotive sector. There may be variation in the importance of various factors from industry to industry.

- The study is conducted only in the Indian scenario. Thus, the result may be different in the case of another country.
- The study is focused on certain small, medium, and large scale enterprises of the Indian automotive sector by applying various parameters in the sample selection. This may be further extended for the manufacturing sector and service sector to get better and more generalized results.
- The sample size was limited to the Indian automotive firms, which potentially limits its application for micro firms and service companies.
- One more issue that is worth mentioning here is that the measures of industry performance adopted in the present research are based on the managers' perceptions, which to some extant may be subjective.
- The effect of other factor like environmental factor has an impact on the overall supply chain performance has not been considered in the present study.

8.5 Scope for future research

The research carried out in the present study is widespread and may be of high use to academicians, researchers, managers, and decision makers etc. Every study has its own limitation in terms of the different issues. These limitations raise the need to extend this work in further studies. The study presents many opportunities that could be explored in future studies. The possible and important scope for future research is presented as below:

- The ISM-based model may be tested in other industries and real world setting by adding or removing some key factors based on the type of industry and tests any correlations among the key factors.
- Similarly, ISM-based model may be tested in other industries and real world setting by adding or removing some barriers based on the type of industry and tests any correlations among the barriers.
- This study can also be applied to automotive clusters analysis and comparison can be made by using the analytic hierarchy process (AHP) or Fuzzy AHP.
- The developed scale can be used to conduct a comparative study between two different sectors. This scale can be further modified as per the specification of a particular sector for the measurement of supply chain performance.

- Apart from the used approachs in this thesis, other techniques may be utilized with a larger sample size. Finally, other integrated techniques like analytic network process (ANP), fuzzy ANP, fuzzy axiomatic design (FAD), quality function deployment (QFD), fuzzy QFD, and TOPSIS could be used for better results.

8.6 Conclusion

This chapter provides a consolidate picture of the entire study. It also provides the research contribution, implications for practitioners and academician, key findings, limitations of the present study, and scope for the future research. It is expected that interactions of the key factors, interactions of the barriers, selection of best supplier, and development of a scale for the measurement of supply chain performance and its impact on firm's overall supply chain performance in the Indian automotive sector, will work as a tool for various acamedicians, researchers and industry's managers. This study touched on various issues of Indian automotive supply chain performance that may be useful in developing a strategy and will be helpful in measuring and improving supply chain performance.

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Appendix

Appendix A

	Department of Management Studies Indian Institute of Technology Roorkee, Roorkee Phone: +91-1332-285678, Fax: +91-1332-273560

Letter from Supervisor,

July, 2011

Dear Participants,

I wish to introduce *Mr. Rajesh Katiyar*. He is a research scholar in the Department of Management Studies and is enrolled for Ph.D. program under my supervision at the Indian Institute of Technology Roorkee (IITR), Uttrakhand, India. His doctoral thesis is a study on "Measurement of supply chain performance in select automotive industries in India". To carry out his research work and to make it more fruitful, I seek your kind cooperation. All information/data collected during the study will be used only for academic research work and strict confidentiality will be maintained. I would like to repeat how grateful I would be if you could assist Mr. Rajesh Katiyar. Thank you for your valuable time.

Thanking you in anticipation,

Yours Sincerely,

Dr. Mukesh Kumar Barua
DoMS, IIT Roorkee

Appendix B

Dear Sir/Madam,
I am Rajesh Katiyar, pursuing my PhD on the topic '*Measurement of supply chain performance in select automotive industries in India'* in the Department of Management Studies, IIT Roorkee. For this, I need your help in data collection to carry out my research. All information given by you would be kept confidential. Thank you so much for your valuable time and kind co-operation.

Part-1

1. Gender: Male Female

2. Educational Qualification:

Diploma	Graduate	Postgraduate	PhD Or Equivalent	Any other

3. Your Position in Organization:

Lower Level Management	Middle Level Management	Senior Level Management

4. Age in Years:

< 25	< 30	< 35	< 40	≥ 40

5. Experience in Years:

< 5	< 10	< 15	< 20	≥ 20

6. No. of Employees:

< 100	< 200	< 500	< 1000	≥ 1000

7. Your Organization's Turnover in (Rs):

1-10 Crores	11-20 Crores	21-30 Crores	31-40 Crores	≥ 40 Crores

Part-2

Following are the key factors/measures of supply chain performance measurement. How important are these for your organization? Please indicate your opinion on the following statements.

A. How important are these key factors/measures under **Plan performance? (1=EUI**=Extremely Unimportant, **2=UI**=Unimportant, **3=SUI**=Somewhat Unimportant, **4=N**=Neutral, **5=SI**=Somewhat Important, **6=I**=Important, **7=EI**=Extremely Important).

Key Factors/Measures	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Order entry method							
Order lead time							
Customer order path							

B. How important are these key factors/measures under **Source performance? (1=EUI**=Extremely Unimportant, **2=UI**=Unimportant, **3=SUI**=Somewhat Unimportant, **4=N**=Neutral, **5=SI**=Somewhat Important, **6=I**=Important, **7=EI**=Extremely Important).

Key Factors/Measures	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mutual assistance in solving problems							
Purchase order cycle time							
Supplier selection							
Buyer-supplier relationship							

C. How important are these key factors/measures under **Make/Assemble/Production/Manufacturing performance? (1=EUI**=Extremely Unimportant, **2=UI**=Unimportant, **3=SUI**=Somewhat Unimportant, **4=N**=Neutral, **5=SI**=Somewhat Important, **6=I**=Important, **7=EI**=Extremely Important).

Key Factors/Measures	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Capacity utilization							
Effectiveness of master production schedule							
Range of product and services							
Product cost							
Quality							
Flexibility							

D. How important are these key factors/measures under **Delivery performance?** **(1=EUI**=Extremely Unimportant, **2=UI**=Unimportant, **3=SUI**=Somewhat Unimportant, **4=N**=Neutral, **5=SI**=Somewhat Important, **6=I**=Important, **7=EI**=Extremely Important).

Key Factors/Measures	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Delivery lead time							
Effectiveness of delivery invoice methods							
On time delivery of goods							
Flexibility of delivery systems to meet particular customer needs							

E. How important are these key factors/measures under **Customer service performance?** **(1=EUI**=Extremely Unimportant, **2=UI**=Unimportant, **3=SUI**=Somewhat Unimportant, **4=N**=Neutral, **5=SI**=Somewhat Important, **6=I**=Important, **7=EI**=Extremely Important).

Key Factors/Measures	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Flexibility to meet particular customer needs							
Customer query time							
Post transaction measures of customer service							

F. How following factors affect the S**upply chain performance**? **(1=EUI**=Extremely Unimportant, **2=UI**=Unimportant, **3=SUI**=Somewhat Unimportant, **4=N**=Neutral, **5=SI**=Somewhat Important, **6=I**=Important, **7=EI**=Extremely Important).

Key Factors/Measures	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Information carrying cost							
Manufacturing cost							
Flexibility of service system to meet customer needs							
Total inventory cost							

Appendix C

Dear Sir/Madam,

Read the following questions and put check marks on the pair-wise comparing matrices. If an attribute on the left is more important than the one matching on the right, put your check mark to the left of the importance "Equal" under the importance level you prefer. If an attribute on the left is less important than the one matching on the right, put your check mark to the right of the importance "Equal" under the importance level you prefer.

With respect to the overall goal *"selection of the best supplier"*

Q1. How important is *Plan (P)* when it is compared with *Source (S)*?

Q2. How important is *Plan (P)* when it is compared with *Manufacturing (M)*?

Q3. How important is *Plan (P)* when it is compared with *Delivery (D)*?

Q4. How important is *Plan (P)* when it is compared with *Customer Service (CS)*?

Q5. How important is *Source (S)* when it is compared with *Manufacturing (M)*?

Q6. How important is *Source (S)* when it is compared with *Delivery (D)*?

Q7. How important is *Source (S)* when it is compared with *Customer Service (CS)*?

Q8. How important is *Manufacturing (M)* when it is compared with *Delivery (D)*?

Q9. How important is *Manufacturing (M)* when it is compared with *Customer Service (CS)?*

Q10. How important is *Delivery (D)* when it is compared with *Customer Service (CS)?*

With respect to the Best supplier		*Importance (or preference) of one main-attribute over another*									
Questions	Attributes	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Attributes
Q1	P										S
Q2	P										M
Q3	P										D
Q4	P										CS
Q5	S										M
Q6	S										D
Q7	S										CS
Q8	M										D
Q9	M										CS
Q10	D										CS

With respect to the main attribute *"plan (P)"*

Q11. How important is *order entry method (OEM)* when it is compared with *order lead time (OLT)*?

Q12. How important is *order entry method (OEM)* when it is compared with *customer order path (COP)*?

Q13. How important is *order lead time (OLT)* when it is compared with *customer order path (COP)*?

With respect to Plan		*Importance (or preference) of one sub-attribute over another*									
Questions	Sub-attributes	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Sub-attributes
Q11	OEM										OLT
Q12	OEM										COP
Q13	OLT										COP

With respect to the main attribute *"source (S)"*

Q14. How important is *supplier selection (SS)* when it is compared with *purchase order cycle time (POCT)*?

Q15. How important is *supplier selection (SS)* when it is compared with *buyer-supplier relationship (BSR)*?

Q16. How important is *supplier selection (SS)* when it is compared with *master assistance in solving problems (MASP)*?

Q17. How important is *purchase order cycle time (POCT)* when it is compared with *buyer-supplier relationship (BSR)*?

Q18. How important is *purchase order cycle time (POCT)* when it is compared with *master assistance in solving problems (MASP)*?

Q19. How important is *buyer-supplier relationship (BSR)* when it is compared with *master assistance in solving problems (MASP)*?

With respect to Source		*Importance (or preference) of one sub-attribute over another*									
Questions	Sub-attributes	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Sub-attributes
Q14 Q15 Q16	SS SS SS										POCT BSR MASP
Q17 Q18	POCT POCT										BSR MASP
Q19	BSR										MASP

With respect to the main attribute *"manufacturing (M)"*

Q20. How important is *effectiveness of master production schedule (EMPS)* when it is compared with *product cost (CU)*?

Q21. How important is *effectiveness of master production schedule (EMPS)* when it is compared with *capacity utilization (PC)*?

Q22. How important is *effectiveness of master production schedule (EMPS)* when it is compared with *quality (Q)*?

Q23. How important is *effectiveness of master production schedule (EMPS)* when it is compared with *flexibility (F)*?

Q24. How important is *effectiveness of master production schedule (EMPS)* when it is compared with *range of product and services (RPS)*?

Q25. How important is *product cost (CU)* when it is compared with *capacity utilization (PC)*?

Q26. How important is *product cost (CU)* when it is compared with *quality (Q)*?

Q27. How important is *product cost (CU)* when it is compared with *flexibility (F)*?

Q28. How important is *product cost (CU)* when it is compared with *range of product and services (RPS)*?

Q29. How important is *capacity utilization (PC)* when it is compared with *quality (Q)*?

Q30. How important is *capacity utilization (PC)* when it is compared with *flexibility (F)*?

Q31. How important is *capacity utilization (PC)* when it is compared with *range of product and services (RPS)*?

Q32. How important is *quality (Q)* when it is compared with *flexibility (F)*?

Q33. How important is *quality (Q)* when it is compared with *range of product and services (RPS)*?

Q34. How important is *flexibility (F)* when it is compared with *range of product and services (RPS)*?

With respect to Manufacturing		*Importance (or preference) of one sub-attribute over another*									
Questions	Sub-attributes	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Sub-attributes
Q20	EMPS										CU
Q21	EMPS										PC
Q22	EMPS										Q
Q23	EMPS										F
Q24	EMPS										RPS
Q25	CU										PC
Q26	CU										Q
Q27	CU										F
Q28	CU										RPS
Q29	PC										Q
Q30	PC										F
Q31	PC										RPS
Q32	Q										F
Q33	Q										RPS
Q34	F										RPS

With respect to the main attribute *"delivery (D)"*

Q35. How important is *flexibility of delivery systems to meet particular customer needs (FDSMPCN)* when it is compared with *effectiveness of delivery invoice methods (EDIM)*?

Q36. How important is *flexibility of delivery systems to meet particular customer needs (FDSMPCN)* when it is compared with *on time delivery of goods (OTDG)*?

Q37. How important is *flexibility of delivery systems to meet particular customer needs (FDSMPCN)* when it is compared with *delivery lead time (DLT)*?

Q38. How important is *effectiveness of delivery invoice methods (EDIM)* when it is compared with *on time delivery of goods (OTDG)*?

Q39. How important is *effectiveness of delivery invoice methods (EDIM)* when it is compared with *delivery lead time (DLT)*?

Q40. How important is *on time delivery of goods (OTDG)* when it is compared with *delivery lead time (DLT)*?

With respect to Delivery		Importance (or preference) of one sub-attribute over another									
Questions	Sub-attributes	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Sub-attributes
Q35	FDSMPCN										EDIM
Q36	FDSMPCN										OTDG
Q37	FDSMPCN										DLT
Q38	EDIM										OTDG
Q39	EDIM										DLT
Q40	OTDG										DLT

With respect to the main attribute *"customer service (CS)"*

Q41. How important is *flexibility to meet particular customer needs (FMPCN)* when it is compared with *post transaction measures of customer service (PTMCS)*?

Q42. How important is *flexibility to meet particular customer needs (FMPCN)* when it is compared with *customer query time (CQT)*?

Q43. How important is *post transaction measures of customer service (PTMCS)* when it is compared with *customer query time (CQT)*?

With respect to Customer service		Importance (or preference) of one sub-attribute over another									
Questions	Sub-attributes	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Sub-attributes
Q41	FMPCN										PTMCS
Q42	FMPCN										CQT
Q43	PTMCS										CQT

With respect to the sub-attribute *"order entry method (OEM)"*

Q44. How important is *Supplier 1* when it is compared with *Supplier 2?*

Q45. How important is *Supplier 1* when it is compared with *Supplier 3*?

Q46. How important is *Supplier 2* when it is compared with *Supplier 3*?

With respect to Order entry method		*Importance (or preference) of one alternative over another*									
Questions	Alternatives	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Alternatives
Q44	Supplier 1										Supplier 2
Q45	Supplier 1										Supplier 3
Q46	Supplier 2										Supplier 3

Similar, with respect to the sub-attribute "OLT, COP, SS, POCT, BSR, MASP, EMPS, CU, PC, Q, F, RPS, FDSMPCN, EDIM, OTDG, DLT, FMPCN, PTMCS" and *"customer query time (CQT)"*

Q47. How important is *Supplier 1* when it is compared with *Supplier 2?*

Q48. How important is *Supplier 1* when it is compared with *Supplier 3*?

Q49. How important is *Supplier 2* when it is compared with *Supplier 3*?

With respect to Customer query time		*Importance (or preference) of one alternative over another*									
Questions	Alternatives	(7/2, 4, 9/2) Absolute	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Equal	(5/2, 3, 7/2) Weak	(5/2, 3, 7/2) Fairly Strong	(5/2, 3, 7/2) Very Strong	(5/2, 3, 7/2) Absolute	Alternatives
Q47	Supplier 1										Supplier 2
Q48	Supplier 1										Supplier 3
Q49	Supplier 2										Supplier 3

Research Publications

Journals

1. Katiyar, R., Barua, M.K. and Meena, P.L. (2014), "Modelling the measures of supply chain performance in the Indian automotive industry", *Benchmarking: An International Journal* {Forthcoming, Emerald}.
2. Katiyar, R. and Barua, M.K. (2014), "Modelling the barriers of supply chain performance measurement in the Indian automotive industries", *International Journal of Intercultural Information Management,* Vol. 4 No. 1, pp. 51-66.
3. Katiyar, R. and Barua, M.K. (2013), "Analysis of interactions among the key enablers of supply chain performance measurement in Indian automotive industry", *Industrial Engineering Journal,* Vol. 6 No. 9, pp. 28-33.

Conferences

1. Prakash, C., Barua, M.K. and Katiyar, R. (2013), "Optimal Ordering Policy for Deteriorating Items with Learning Effect under Inflationary Environment", *23rd International Business Research Conference,* Melbourne University, Australia, November 18-20, 2013.
2. Katiyar, R. and Barua, M.K. (2013), "Modelling the barriers of supply chain performance measurement in Indian automotive industries", *International Conference on Management and Business Innovation-ICOMBI,* Department of Management Studies, Malaviya National Institute of Technology, Jaipur, May 18-19, 2013, pp.15-21.
3. Katiyar R. and Barua, M.K. (2012), "A study of factors affecting Indian automotive supply chain", *Twelfth Global Conference on Flexible Systems Management on Theme Systemic Flexibility and Business Agility,* Global Institute of Flexible Systems Management, University of Vienna, Austria, July 30-August 1, 2012, pp. 647-659.
4. Katiyar R., Barua, M.K. and Balon, V. (2012), "Role of marketing factors in Indian automotive supply chain", *National Conference on Emerging Challenges for Sustainable Business,* Department of Management Studies, IIT Roorkee, Uttarakhand, June 1-2, 2012, pp. 1808-1822.
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6. Balon, V., Sharma, A.K., Barua, M.K. and Katiyar, R. (2012), "A performance measurement of green supply chain management in Indian auto industries", *National Conference on Emerging Challenges for Sustainable Business,* Department of Management Studies, IIT Roorkee, Uttarakhand, June 1-2, 2012, pp. 1563-1569.

7. Katiyar, R. and Barua, M.K. (2011), "A selective study of supply chain performance measurement: Current and future's point of view", *Conference on Excellence in Research and Education*, Indian Institute of Management Indore, Madhya Pradesh, May 13-16, 2011.

8. Katiyar, R. and Barua, M.K. (2011), "A study on performance measures and metrics in a supply chain: A review", *First National Conference of Research Scholars in Management*, ABV-Indian Institute of Information Technology and Management, Gwalior, Madhya Pradesh., March 26-27, 2011, pp. 36.

Paper(s) Under Review/Communicated

1. Katiyar, R., Barua, M.K. and Meena, P.L. (2014), "Analyzing the interactions among the barriers of supply chain performance measurement: An ISM with fuzzy MICMAC approach", *Global Business Review* {Under Review}.

2. Katiyar, R., Barua, M.K. and Meena, P.L. (2015), "Multi-attribute comparison of the Indian automotive suppliers using fuzzy AHP approach", *Expert Systems with Applications* {Communicated}.

3. Katiyar, R., Barua, M.K. and Meena, P.L. (2015), "Development of a supply chain performance model", *International Journal of Production Economics* {Communicated}.