Development of an Integrated Framework for Aligning New Product Development and Supply Chain Management Activities

PhD Thesis

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This thesis is submitted as partial fulfillment of PhD program in

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CERTIFICATE

This is to certify that the thesis entitled **“Development of an integrated framework for aligning new product development and supply chain management activities”**, being submitted by **Mr. Ankur Pareek** (2007/RME/001) to Malaviya National Institute of Technology Jaipur, for the award of the degree of Doctor of Philosophy in Mechanical Engineering, is a bonafide record of original research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirement for the submission of this thesis, which has reached the requisite standard. The results contained in this thesis have not been submitted in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

In today's world where customer preferences are changing rapidly and industries are trying their best to match customer expectations, product design has emerged as a strategic option to gain competitive advantage. Firms are facing the challenge of keeping pace with fast and unpredictable changes in demand pattern. To meet this challenge, apart from design competence, firms must also ensure good coordination with upstream and downstream supply chain partners, to deliver at the right time, in the right quantity, and at the right cost. Effective supply chain management holds the key to reducing supply cost as well as lead time, in order to survive the cut-throat competition. Thus, both new product development and supply chain management activities play important role in business performance. Most studies so far have focused on individual influence of either new product development or supply chain management on competitive advantage. However, better results have been obtained lately where the two activities are carried out in close coordination. It is therefore of interest to study the effect of alignment between NPD and SCM activities on competitive advantage.

This research develops an integrated framework that aligns new product development and supply chain management activities, and measures the influence of resulting alignment on competitive advantage in comparison to other established competitive priorities.

The study explores ten linkages between NPD and SCM activities through an extensive literature review, and identifies five key linkages out of them that are prominent in context of automotive supply chain. It further develops a reliable and valid instrument for measuring the variables entering the proposed integrated model, and uses the instrument for collecting empirical evidence from Indian automobile industry through a large-scale web based survey. It analyzes

the responses using analytic network process (ANP) to capture the effect of inter-dependence among variables. The findings are validated by means of three longitudinal in-depth case studies, one each at the supplier, manufacturer, and dealer stage of the Indian automotive supply chain.

The findings support the hypothesis that NPD-SCM alignment has a positive influence on competitive advantage, comparable to other established competitive priorities such as cost, quality, delivery, flexibility, and innovation. Among the key linkages, early supplier involvement, voice of customer, modularity, and supply chain responsiveness have strong positive influence on aligning NPD and SCM activities, while postponement is found to be significant only towards the customer end of the supply chain.

This research makes three significant contributions to operations management literature. First, it develops an instrument for measuring NPD-SCM alignment. Second, it identifies key linkages for aligning NPD and SCM activities, and verifies four of them (early supplier involvement, voice of customer, modularity, and supply chain responsiveness) as significant contributors in achieving NPD-SCM alignment. Third and most important, this research establishes NPD-SCM as a significant competitive priority in Indian automobile industry.

The study also provides scope for improvement and recommends some directions for future research, in form of customer linkage analysis and optimization, model scope and measurement techniques, balance of power among supply chain partners, and impact of technology turbulence and business uncertainties.

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LIST OF ABBREVIATIONS

S.No.	Abbreviation	Full form
1.	AHP	Analytic hierarchy process
2.	ANP	Analytic network process
3.	CA	Competitive advantage
4.	3DCE	Three dimensional concurrent engineering
5.	DfSC	Design for supply chain
6.	ESC	Extended supply chain
7.	ESI	Early supplier involvement
8.	MCDM	Multi criteria decision making
9.	MOD	Modularity
10.	NPD	New product development
11.	NSA	NPD-SCM alignment
12.	POS	Postponement
13.	QFD	Quality function deployment
14.	RM	Rhythm matching
15.	SCM	Supply chain management
16.	SCR	Supply chain responsiveness
17.	VOC	Voice of customer

CHAPTER 1

INTRODUCTION

1.1 Background

Globalization and economic reforms have been amongst major factors in shaping modern world's progress. However, they have also made today's business environment more complex, characterized by rapid advancement in technology, rising customer expectations, and excess of supply in comparison to demand. This has resulted in a fierce competition between rival companies, who are left with no other choice but to improve their competitiveness in order to survive in the dynamically changing business conditions. Firms need to respond rapidly, effectively, and efficiently to technology-oriented and customer-driven market dynamics, in order to sustain and further improve their competitive advantage.

The concept of competitive advantage dates back to the industrial revolution, when factories started using division of labour and mass production to cut down manufacturing cost, and hence increase profit. Cost, thus emerged as an important weapon for gaining competitive advantage over rivals. After some decades, with most companies offering competitive price, superior product quality was successfully used by many firms to win customer orders. Few years later, as customer satisfaction became more and more important, dependable delivery was adopted by some firms in order to remain competitive. By the turn of the century, rapid progress in science and technology enabled companies to manufacture new types of products, and/or offer more product variety to attract more and more customers. Flexibility and innovation thus became the new measures of gaining competitive advantage. Since then, there have been many other factors of improving competitiveness, but most of them have been specific to a particular type of industry, and thus could not be generalized. The literature on competitiveness widely recognizes the five factors – cost, quality, delivery, flexibility, and innovation, as universally accepted measures of improving competitive advantage.

Today's business scenario is characterized with rapid new product introductions, shorter product life cycles, and increasingly knowledgeable customers. Customers now-a-days have better access to products and services across the whole world. The rising competition among companies has further made customers more powerful and demanding. Pride of ownership has become an important parameter of customer satisfaction today, with customers expecting innovative features, shortest lead time, superior quality, and competitive cost. This has resulted in high level of uncertainty and complexity in the business environment. Firms are finding it difficult to cope with rapid design changes and decreasing product and technology lifecycles. They are facing a great pressure to introduce innovative design features, cut down lead times, and incorporate flexibility to adjust to the unpredictable demand patterns. These challenges have created a need for continuous change process within organizations, involving rapid technological changes in almost all the areas of business, to come out with innovative products and improved manufacturing processes. Due to all these reasons, two activities have gained significant importance in today's business environment, and hold the key to success. *New product development* (NPD) activity aims at developing innovative products or making changes in existing product design, in order to meet dynamically changing customer expectations. For achieving the task, it is equally important for firms to supply these attractive products at minimum cost and in shortest possible time, thus calling for effective *supply chain management* (SCM).

1.1.1 New product development

New products are not only to be designed on paper, but also have to be manufactured and supplied to the desired level of customer satisfaction. In the race to manufacture and supply new products, design people have to interact with suppliers, customers, operations and logistics personnel. New product development refers to a set of activities that include market survey, assessment of customer needs, strategic concept building, technical design, coordination with production capabilities, logistics, etc. It generally involves product design, feasibility and economics of manufacturing the designed product, prototype and pilot testing.

NPD activity has a deep impact on competitive advantage in today's business environment, as design / features of a product influence its market demand and hence competitiveness of the firm. Porter (1985) refers to product design as a discrete but value adding activity, and a firm achieves competitive advantage by performing these activities more cheaply and better than its competitors.

1.1.2 Supply chain management

In the era of globalization, companies soon realized the power of forming strategic alliance in form of supply chains. Supply chain consists of all parties involved- supplier, manufacturer, distributor, retailer and the customer, directly or indirectly in fulfilling a customer request. For example, global supply chains may have suppliers and manufacturers situated in low cost locations such as Asia, distributors in Middle East and Latin America, and retailers and customers in Europe and America. Supply chain is a system that creates value by integrating suppliers, manufacturers, distributors, and customers in terms of material, financial, and information flows (Fiala, 2005). Supply chain management (SCM) is a set of practices that focus on building strategic networks, and manage flow of material, cash and information upstream and downstream (Li et al., 2006; Donlon, 1996; Tan et al., 2002).

Today the competition is no longer between individual organizations; rather supply chains are competing with each other to please the customer (Academic Alliance Forum, 1999; Christopher and Peck, 2004; Li et al., 2005). Supply costs constitute a significant percentage of the total cost, and therefore, organizations all over the world are re-organizing and streamlining their supply chains. Generally the focus is on reducing supply costs, but sometimes an agile supply chain is desired even if it means greater logistics costs. The supply chain has to be responsive to match the product characteristics (Fisher, 1997; Selldin & Oldhager, 2007). Successful firms are those that effectively coordinate across all stages of the supply chain, from their supplier's supplier to their customer's customer (Lummus and Vokurka, 1999). The literature recognizes supply chain management as an important factor for improving competitive advantage in highly competitive markets (Choi and Hartley, 1996; Chen and Paulraj, 2004; Li et al., 2006).

Thus over the years, both new product development and supply chain management activities have been individually used by industry to gain competitive advantage.

The current research shows that better results can be obtained by aligning new product development and supply chain management activities. NPD-SCM alignment yields magical results, such as reduced time-to-market, better flexibility, and improved performance; especially in sectors such as electronics / computers, manufacturing, and automobile. It may be due to the fact that these industries offer products that are either innovative (electronics / computers), or offer a large variety (manufacturing), or both (automobile). In such type of products, both new product development and supply chain management activities play important roles in business success, and therefore these industries tend to get further benefited by the alignment between the two.

1.1.3 Aligning new product development and supply chain management

Generally, first a product is designed to meet or exceed customer expectations (and thus to maximize demand), and then the supply chain is designed to manufacture and supply this product. NPD team aims at a design that generates maximum demand, while SCM people want a design that results in minimum supply chain costs. These different objectives may lead to conflicts and clashes between NPD and SCM teams. Further, changes in product design call for changes in supply chain design. Thus while designing the product, issues related to the entire supply chain (which includes manufacturing as one stage) must be taken into account. Better results can be obtained if NPD and SCM activities are aligned together. Research shows that different aspects of supply chain management such as transportation planning, warehouse selection, and supplier selection should be coordinated with new product development activities in order to minimize the total product cost.

Based on the review of existing literature, ten prominent linkages have been identified that tend to strengthen the alignment between new product development and supply chain management. These linkages are -- match between product design and supply chain, rhythm matching, extended supply chains, supply chain responsiveness, voice of customer, early supplier involvement, modularity, postponement, design for supply chain, 3-dimensional concurrent engineering. These linkages have been described in detail along with their role in improving NPD-SCM alignment in section 2 of this thesis. Here it is sufficient to mention that the functional areas where these linkages were strong have witnessed some visible benefits of the coordination. This research shows that competitiveness of a company and the entire supply chain can be improved through proper alignment between NPD and SCM activities. NPD-SCM alignment is perceived to improve competitive advantage directly, as well as indirectly by positively influencing cost, quality, delivery, flexibility and innovation.

Many attempts have been made in the past to measure competitiveness. A number of performance indicators have been developed by many researchers. Most of them are based on frameworks that capture influence of multiple dimensions of business activities involving a number of elements that influence competitiveness of the organization. Some popular indicators include Performance Measurement Matrix (Keegan et al., 1989), Results and Determinants Framework (RDF) (Fitzgerald et al., 1991), Balanced Scorecard (BSC) (Kaplan and Norton, 1992), Cambridge Performance Measurement Framework (CPMF) (Neely et al., 1995), Integrated Performance Measurement Framework (IPMS) (Medori and Steeple, 2000), Performance Prism (Neely and Adams, 2001), Asset Process Performance (APP) (Ambastha and Momaya, 2004), and Supply Chain Operation Reference Model (SCOR) (Supply-Chain Council, 2006). Most of these frameworks have their own merits and limitations, and are best suited in a particular environment. There is a lack of consensus on effectiveness of any single measure that can be applied under all situations. In a real world situation, majority of factors affecting competitiveness influence each other. However, only a few performance measures capture the holistic picture including the effect of inter-dependence among factors affecting competitiveness. Also generally practitioners are interested in finding relative weights of the factors affecting competitiveness, so that they may set their priorities accordingly. But barring very few performance indicators, there is a dearth of frameworks that can prioritize the influence of various elements on competitiveness. Thus, these constraints necessitate development of new integrated frameworks for measurement of competitiveness that can be customized as per the situation, and captures the effect of inter-dependence as well.

In this research, an integrated framework for measuring NPD-SCM alignment and has been developed using Analytic Network Process (Saaty, 1996), and its resulting effect on competitiveness of Indian automotive supply chain, specially the passenger car segment has been analyzed. ANP is multi-criteria decision making technique that captures interdependence among variables and allows a more systematic analysis (Jharkharia and Shankar, 2007). It has been effectively used in making decisions regarding energy policy planning, product design, supplier selection, equipment replacement (Sarkis, 1998), and for prioritizing various variables affecting competitiveness of entire supply chain (Joshi et al., 2013).

High variety of products, increasing rate of innovation, and presence of global supply chains have been the prominent reasons for selecting automobile industry for the study. Automotive industry in India comprises of auto component suppliers (OEMs), automobile manufacturers, dealers and service centers; and mainly produces four types of vehicles, viz. two wheelers, passenger cars, commercial vehicles, and special purpose vehicles. Among these, passenger car segment is the most competitive one, having a high degree of both new product development and supply chain management activities. In order to remain competitive, almost all passenger car manufacturers are trying to introduce more and more innovative features, and attempting to cut down cost and lead time through global sourcing. Thus, both NPD and SCM activities are important for gaining competitive advantage in passenger car segment of the Indian automotive industry. It is hypothesized that proper alignment between the two is expected to improve competitiveness even further.

1.2 Research motivation

Automobile industry in India is estimated to be a $ 65 billion industry (SIAM, 2012). It has experienced a phenomenal growth in recent years mainly due to the entry of major giants such as Toyota, Nissan, Renault, Skoda, and Volkswagen, into the already competitive passenger car market which already had some big players such as General Motors, Ford, Honda, Maruti, Hyundai, Tata motors, Mahindra & Mahindra, and Hindustan motors. There was a high foreign direct investment (FDI) inflow of US$ 7,518 million during April 2000 to November 2012, which accounted to nearly 4 per cent of the total FDI inflows (SIAM, 2010). With the latest entry of big players like Volvo, Jaguar, Audi, and BMW, automobile industry is expected to grow even further. The vision of Automotive Mission Plan 2006-2016 aims India "to emerge as the destination of choice in the world for design and manufacture of automobiles and auto components, with output reaching a level of US$ 145 billion accounting for more than 10 percent of the national GDP and 30-35 percent of industry GDP, providing additional employment to 25 million people by 2016 (SIAM, 2010).

The fact that automobile industry is a major sector of economic development in India ignites interest, and thus becomes the main motivation for this research. Since the sector is of national importance, its strengths and weaknesses need to be evaluated, and careful planning is required to convert challenges into opportunities. For this, an extensive research at the aggregate industry level is required to identify factors that would improve its competitiveness. Most of the previous research studies done on automotive sector have focused on organizational level, and have identified some performance measures and linked them with competitiveness. Since it is now well established that competition is no longer between individual organizations but between supply chains, research is required at supply chain level. Also, very few works have reported prioritization of competitive priorities and the factors affecting them, especially taking into account the interdependence amongst them. Existing literature on NPD-SCM alignment is largely conceptual with research primarily based on case studies at organizational level. Empirical research at supply chain level needs to be taken up for evaluating alignment between new product development and supply chain management, and the resulting impact of this alignment on competitiveness.

In fact, an integrated framework across the entire automotive supply chain needs to be developed that can prioritize the effect of some key linkages on NPD-SCM alignment, as well as evaluate the impact of NPD-SCM alignment on competitive advantage relative to the established competitive priorities. This perceived gap in existing literature is the prime motivation to carry out research on this topic.

1.3 Research objectives

It is expected that performance of an organization / supply chain can be improved through proper alignment between new product development and supply chain management. The overarching aim of this research is to integrate the two important areas – NPD and SCM, and study the influence of their alignment on competitive advantage. In the previous section, some research gaps in existing literature have been identified in the form of various limitations and shortcomings of past studies. These gaps demand an integrated study of NPD-SCM alignment and its resulting influence on competitiveness across the entire automotive supply chain. The specific objectives of this research, in context of the Indian automotive industry, specifically the fast growing passenger car segment are:

1. To investigate whether any alignment exists between NPD and SCM activities, and identify its determinants.

2. To measure the current level of NPD-SCM alignment.
3. To analyze the relative contribution of various linkages in improving NPD-SCM alignment.
4. To evaluate the impact of NPD-SCM alignment in improving competitive advantage, in comparison to the already established factors – cost, quality, delivery, flexibility, and innovation.
5. To identify the reasons for any disparity among research findings across different stages of the Indian automotive supply chain, and draw managerial implications.

An integrated framework has been developed in this research that fulfils the above mentioned objectives. The integrated framework shall be discussed in detail in chapter 3 of this thesis.

1.4 Research approach

This study aims at measuring the effect of various linkages between new product development and supply chain management practices on NPD-SCM alignment, and evaluates the effectiveness of NPD-SCM alignment in improving competitiveness, in comparison to the already established factors – cost, quality, delivery, flexibility, and innovation. To address the gaps in literature, an integrated framework has been developed to evaluate and prioritize the effect of various linkages on NPD-SCM alignment, and the impact of this NPD-SCM alignment on competitiveness. An empirical study of the research objectives has been carried out through an online questionnaire survey across the passenger car segment of Indian automotive supply chain. As in any empirical study, reliable and valid instruments are needed to evaluate the constructs involved in the relationships under study. A survey questionnaire has been developed through literature review, as well as through adoption with modifications from earlier works (Li et al., 2006; Thate, 2007). Development of a valid and reliable instrument for evaluating NPR-SCM alignment is one of the contributions of the current research. The questionnaire was administered online for data collection. Analytic network process was used for analyzing the responses to test the hypothesized relationships, as it easily models the multiple criteria decision problems having inter-dependence among dependent elements. The findings of the survey have been validated through three longitudinal in-depth case studies – one each at supplier, manufacturer, and customer stage of the supply chain.

Through development of the integrated framework and a valid instrument for evaluating NPD-SCM alignment, and by providing empirical evidence of the presence of NPD-SCM alignment in Indian automotive industry and its impact on competitiveness, it is expected that this research will offer a useful guideline for evaluating and improving NPD-SCM alignment and competitive advantage in automotive industry, thus facilitating further research in this area.

1.5 Structure of thesis

The remainder of this thesis is organized in the following manner:

Chapter 2 presents a comprehensive review of literature on new product development, supply chain management, linkages influencing NPD-SCM alignment, and competitiveness metrics. A brief account of various multi-criteria decision modelling (MCDM) techniques including analytic network process has also been given.

Chapter 3 outlines the research framework for capturing NPD-SCM alignment and its impact on competitiveness, including the methodology to address the research objectives.

Chapter 4 describes development of the research instrument in form of a questionnaire, and the details of data collection through an internet based survey.

Chapter 5 exhibits data analysis of the empirical study using analytic network process and exhibits the findings.

Chapter 6 is a collection of three longitudinal in-depth case studies which were carried out to validate the research findings mentioned in chapter 4. These case studies have been carried out across three different stages of the Indian automotive supply chain – supplier, manufacturer, and customer.

Chapter 7 discusses the results by comparing the findings of empirical study and the three case studies. A detailed discussion on research findings and how they relate to the research objectives has been included to gain ample insight into relationships between various linkages, NPD-SCM alignment, and various competitive advantage metrics. The chapter also concludes the thesis through a summary of research findings, major contributions, managerial implications, limitations of the present study, and directions for future research.

Appendices A and B provide details of questionnaire developed for online survey of research objectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The starting point of this research is the hypothesis that new product development and supply chain management activities can be aligned to improve competitive advantage. To prove the hypothesis, it is important to first of all explore the factors or linkages that contribute in aligning these two important business functions. For the purpose, an exhaustive review of operations management, literature particularly on new product development and supply chain management has been carried out to identify the various linkages that help in aligning NPD and SCM activities. Literature survey on competitive advantage has also been carried out in order to understand the fundamentals of competitiveness, and various factors influencing it. Some important performance measures of competitive advantage have been highlighted on the basis of past research. Few mathematical tools of multi-criteria decision making (MCDM) techniques have been reviewed, with special focus on analytic network process (ANP), which has been used as the main mathematical tool for data analysis in this research.

The chapter is organized in three sections. Section 2.2 presents the literature review on NPD-SCM alignment. It is further divided into three sub sections: the first two explain basic concepts of new product development and supply chain management, while the third discusses various linkages between NPD and SCM in detail. Section 2.3 briefly presents literature survey on competitive advantage. Finally, an introduction to various MCDM techniques and review of literature on ANP is presented in section 2.4.

Table 2.1 exhibits the details of articles reviewed in the area of alignment between new product development and supply chain management in form of work published in various reputed international journals, conferences, and books.

TABLE 2.1: Overview of articles reviewed

Journal	No. of papers
Business Horizons	2
Business Intelligence Journal	1
California Management Review	2
Cambridge Journal of Economics	1
Chinese Management Studies	1
Computers and Chemical Engineering	1
Computers in Industry	1
Decision Sciences	4
Decision Support Systems	1
Design Studies	1
Energy Policy	1
European Business Review	1
European Journal of Innovation Management	1
European Journal of Operation Research	10
European Journal of Purchasing & Supply Management	2
European Management Journal	1
Expert Systems with Applications	1
Global Journal of Flexible Systems Management	1
Harvard Business Review	6
IEEE Transactions on Components, Hybrids & Manufacturing Technology	1
IEEE Transactions on Engineering Management	6
IIE Transactions	1
Industrial Management & Data System	3
Industrial Marketing Management	2
Information Intelligence Systems, Technology and Management	1
Information and Software Technology	1
Interfaces	2
International Journal of Advance Manufacturing Technology	1
International Journal of Computer Agile Manufacturing Systems	1
International Journal of Business	1
International Journal of Computer and Information Science	1
International Journal of Computer Integrated Manufacturing	1
International Journal of Electronic Commerce	1
International Journal of Forecasting	1

International Journal of Integrated Supply Chain Management	1
International Journal of Logistic Management	2
International Journal of Logistic Research & Applications	2
International Journal of Modeling in Operations Management	1
International Journal of Operations & Production Management	10
International Journal of Physical Distribution & Logistic Management	10
International Journal of Production Economics	16
International Journal of Production Research	5
International Journal of Productivity and Performance Management	1
International Journal of Technology and Globalization	1
International Journal of Technology Management	1
International Journal of Services & Operations Management	6
International Journal. of Value Chain Management	1
Journal of Business Research	1
Journal of Business in Developing Nations	1
Journal of Business Strategy	1
Journal of Construction Engineering and Management	1
Journal of Engineering & Technology Management	2
Journal of Fashion Marketing & Management	1
Journal of International Management	1
Journal of Japanese Society for Quality Control	1
Journal of Manufacturing Technology Management	4
Journal of Marketing	2
Journal of Marketing Management	1
Journal of Materials Processing Technology	1
Journal of Operations Management	20
Journal of Production Innovation Management	3
Managing Service Quality	1
Management Science	8
Manufacturing & Service Operations Management	2
Measuring Business Excellence	1
Omega: International Journal of Management Science	4
Production and Operations Management	3
Production Planning and Control: The Management of Operations	1
Quality Management Journal	1
Quality Progress	1
Renewable and Sustainable Energy Reviews	1
Research in Engineering Design	1
Research Policy	1
Review of Economic Dynamics	1
Sloan Management Review	5
Strategic Management Journal	1
Supply Chain Management- An International Journal	5

Technovation	5
The Journal of Grey Systems	1
Total Quality Management	1
Transportation Journal	1
World Academy of Science, Engineering and Technology	1
World Review of Entrepreneurship, Management and Sustainable Development	1
Others (books / conference proceedings / working papers / dissertations)	33
Total	**240**

2.2 NPD-SCM alignment

The interaction between new product development and supply chain management activities has recently caught attention of researchers and is increasingly gaining momentum. While the initial phase comprised of predominantly conceptual research, some quantitative research works have been taken up recently. Furthermore, conceptual theories have been empirically tested through measurement of actual performance. The reviewed papers cover a variety of industries, but it seems that research is more popular in sectors such as manufacturing, automobile and electronics / computers, which account for nearly three-fourth of total articles. It may be due to the fact that these industries offer products that are either innovative (electronics / computers), or offer a large variety (manufacturing), or both (automobile). In such types of products, both new product development and supply chain management activities play important roles in business success, and therefore these industries tend to promote research and development in these areas. Case study seems to be the most widely used qualitative methodology. In quantitative research, mathematical modeling including optimization, hypothesis testing, and regression analysis seem to be more popular. Other methods like survey and concept building have also been used. Few researchers have also used other tools like fuzzy / neural networks, design of experiment, algorithms and heuristic methods.

Individually, there is ample amount of literature available on new product development and supply chain management. However, the focus in this section is to review the literature that deals with the interaction between the NPD and SCM. The review is presented in three parts: first, the basics of new product development and some of the related concepts that influence the interaction have been discussed; next section presents the concept of supply chain management and coordination. Lastly, a holistic perspective on the main issue of interaction between NPD and SCM is presented by classifying it into ten linkages. The main objective of this section is to review and analyze the research conducted in this area, and thereby identify key research gaps for future work.

2.2.1 New product development

New product development (NPD) comprises of all activities that lead to transformation of a concept into a prototype. Krishnan and Ulrich (2001) define product development as the transformation of a market opportunity into a product available for sale, and describe it as a deliberate business process involving hundreds of decisions. NPD has become one of the most powerful weapons for gaining competitive advantage in the today's globalized marketplace. One study suggests that product design along with production process influence about 80% of manufacturing costs, approximately 50% of order lead time and business complexity, and nearly half of quality issues (Child et al., 1991). Walsh et al. (1988) define product design as the configuration of elements, material and components that give a product its attributes of function, appearance, durability and safety. According to them product design is far more important than price alone in determining the competitiveness of firms. It enables firms to differentiate themselves from their competitors. Porter (1985) also refers to product design as a discrete but value adding activity, and a firm achieves competitive advantage by performing these activities more cheaply and better than its competitors.

More and more industries are realizing this fact and are devoting significant resources and efforts to improve their product design as well as new product development activities, to come out with best possible design and the most economic way to produce it. Product design and development has a deep impact on the quality of the product and its fitness for use. Some important concepts influencing product design and development are mentioned below.

2.2.1.1 Value Engineering

The value of a component (and consequently its design) is measured as the ratio of its function to its cost. Each design feature is evaluated to find out if its inclusion adds more value to the product in comparison to the cost of adding it. It thus separates non-value adding costs from value adding activities in product design (Cook and Wu. 2001, Cooper and Slagmulder, 1997). Value engineering helps in eliminating waste design features and thus saves the cost, time and effort of developing them.

2.2.1.2 Concurrent Engineering

Sometimes the process planning department finds it difficult to manufacture a product due to certain design features which are either not possible to produce or call for special equipment like expensive tooling and fixtures. Such problems can be avoided if the production capabilities are considered during design and development phase. Concurrent engineering refers to simultaneous design of the product and the process by which it will be manufactured. It generally results in reduction in time-to-market, risk and cost, as well as improvement in quality, innovation and customer satisfaction (Balasubramanian and Mahajan, 2001; Koufteros et al., 2002).

2.2.1.3 Kano model

In the mid 1980’s, Noriaki Kano developed a customer requirements analysis framework, which became popular as the Kano model (Kano et al., 1984). It maps product design features with customer satisfaction, and classifies product features into three categories. Expected or basic features are those whose absence causes dissatisfaction to customers but presence does not cause any delight. Delighters or exciters are the features that are not expected by customers, therefore they result in delight when present, but their absence does not result in dislike. Linear features cause delight to customers when present and dislike when absent. The model has been used as an important tool in new product development to identify innovative design features. It captures the voice of customer which can be included in product design, leading to a greater degree of customer satisfaction.

2.2.1.4 Quality Function Deployment

Quality function deployment is a method for developing a targeted level of design quality aimed at satisfying the consumer, by translating the consumer's demand into design targets and major quality assurance points, to be used throughout the production phase. QFD is an important tool for making design trade-off decisions between component alternatives (Cook and Wu, 2001; Chan and Wu, 2002). It is a way of assuring quality while the product is still in the design stage (Akao, 1990; Mizuno and Akao, 1978). If applied properly, QFD has demonstrated significant reduction in cost and development time. For example, by applying QFD, Toyota reported a 20% reduction in start-up costs on the launch of a new van in October 1979; a 38% reduction in November 1982; and a cumulative 61% reduction in April 1984. During this period, the product development cycle (time to market) was reduced by one-third with a corresponding improvement in quality because of a reduction in the number of engineering changes (Sullivan, 1986). Quality function deployment results in a systems engineering approach which prioritizes product development process. It also benchmarks and assures that product quality is at a level which is defined by the customer.

2.2.2 Supply chain management

The design of production and distribution systems has been an active area of research over the last 30 years. Today it is not a company, but the entire supply chain that has become the unit of competition (Goldman et al., 1995; Bowersox et al., 1999; Christopher, 2000). Supply chain comprises of raw material and component suppliers, manufacturers, distributors, retailers and finally customers. It thus refers to all the parties involved, directly or indirectly, in fulfilling customers' request (Chopra and Meindl, 2007). Demand and supply relationship is found to influence the business environment (Fine, 1998; Cox et al., 2000; Kehoe et al., 2007; Sharifi et al., 2006). The literature on the subject has focused mainly on the physical structure and the operational characteristics of supply chains. However, growing attention has been placed on the areas of determining strategic direction, formation of alignment models and implementing methodologies for demand networks (Fisher, 1997; Fine et al., 2005; Kaipia and Holmström, 2007). Approaching development and management of demand networks through alignment of strategies and operations within the networks has been a focal point in many recent works (Kopczak and Johnson, 2003). Research on SCM can be broadly categorized into the following sub-sections.

2.2.2.1 Supply chain design and coordination

Physical design of various stages of supply chain, viz. plant facilities, transportation modes and nodes, warehouse, distribution locations, etc. affects the ability of the supply chain to satisfy customer demand (Harrison, 2001). Decisions on the suppliers' geographic locations are among important factors that affect supply chain design (Fine, 1998). Supply chain design (SCD) has been an emerging research area since last 25 years. Whereas the initial work was based on the physical design, performance and analysis of supply chains, recent literature focuses more on the strategic issues related to design of supply chains such as its alignment with operations (Fisher, 1997; Lamming et al., 2000; Kehoe et al., 2007). Business performance in today's world is significantly influenced by supply chain coordination, which involves the management of information, cash and material flows, and the collaboration of supply chain partners in product development (Swaminathan and Tayur, 2003).

2.2.2.2 Lean and agile supply chains

Supply chains have been classified as lean (efficient) and agile (responsive) by some researchers (Naylor et al., 1999; Mason-Jones et al., 1999; Aitken et al., 2002). The concept of lean supply chains gained prominence in 1990s, stressing on elimination of all waste, JIT and supplier integration (Womack and Jones, 1996). While lean supply chains proved successful for products having stable demand pattern, the complexity and demand uncertainty of innovative products call for high level of responsiveness, and thus require agile supply chains. The concept of manufacturing agility was applied to supply chains (Harrison et al., 1999) which became the newly accepted units of business. Supply chain agility is the ability of the supply chain to proactively respond to changing business environment by quickly reconfiguring its network and operations according to the dynamically changing needs of the market. The philosophy is similar to that of agile manufacturing, and focuses on "responsiveness" (Lee and Lau, 1999; Christopher and Towill, 2001).

2.2.3 Linkages between NPD and SCM

Researchers argue that the real benefits of linking NPD with SCM are realized if the integration happens at early stages of design. For example, according to Key (1990) and Aseidu and Gu (1998), over three fourth of the cost reduction opportunity lies before the design is frozen. Another study by Hausman et al. (2002) suggests that a discrete manufacturer can save roughly 20% in development cost, 12% in development time, and about 7% in manufacturing cost through effective collaboration with its supply chain partners.

Hayes and Wheelwright (1979, 1984) attempted to explore linkages between product design features and the type of process, and proposed a product-process matrix describing the best fit between product and process designs. The model has been empirically tested and widely recognized in literature (Spencer and Cox, 1995; Sifazadeh et al., 1996; McDermott et al., 1997; Ahmad and Schroeder, 2002). Over the period of time, with supply chains becoming units of competition rather than manufacturing organizations, researchers started aligning supply chains with product design. Cohen and Fine (1998) and Fine (1998, 2000) emphasized on the design of supply chain along with product and process design. Changes in the existing product range or introduction of new products can have economic implications on the existing supply chain networks, and thus its performance. If the supply chain issues are not handled properly during product introduction / diversification phase, they may lead to major problems such as delayed introduction and / or inappropriate product quality (Slamanig and Winkler, 2012).

In this literature review, an attempt has been made to explore the inter-action between new product development and supply chain management activities and classify them as linkages. Some prominent linkages and the authors who have worked on them are summarized in Table 2.2.

TABLE 2.2: Classification of literature into linkages between NPD and SCM

S.no.	Linkages	Authors
1	Match between product design & supply chain	Childerhouse et al. (2002), Fisher (1997), Huang et al. (2002), Khan and Creazza (2009), Kiapia and Holmström (2007), Langenberg et al. (2012), Lee (2002), Mansoornejad et al. (2010), Pero et al. (2010), Ramdas and Spekman (2000), Selldin and Olhager (2007), Verdouw et al. (2010)
2	Rhythm matching	Amini and Li (2011), Amini et al. (2012), Calantone and Di Benedetto (2000), Dacko et al. (2008), Lin et al. (2010)
3	Extended supply chains	Christopher (1998, 2000), Fandel and Stammen (2004), Harrison et al. (1999), Lummus and Vokurka (1999, Svensson (2000), Van Hoek et al. (2001) Lummus (1999), Svensson (2000), Van Hoek (2001)
4	Supply chain responsiveness	Childerhouse et al. (2002), Ismail and Sharifi (2006), Koufteros et al. (2010), Liu et al. (2009), Malhotra and Mackelprang (2012), Mentzer (2004), Naylor et al. (1999), van Hoek and Mitchell (2005), van Hoek and Chapman (2007)
5	Voice of customer (VOC)	Christopher and Towill (2001, 2002), Griffiths and Margetts (2000), Lau (2011), March-Chordà et al. (2002), Matzler and Hinterhuber (1998), Redfern and Davey (2003), Song and Swink (2009), Swink (1998), Tan and Pawitra (2001)
6	Early supplier involvement (ESI)	Anderson and Drejer (2009), Bates and Slack (1998), Bidault et al. (1998), Bonaccorsi and Lipparini (1994), Cagli et al. (2012), Dowlatshahi (1998), He et al. (2012), Hsuan (1999), Khan et al. (2008), Lettice et al. (2010), McCutcheon et al. (1997), Mikkola and Larsen (2006), Parente et al. (2011), Peck (2005), Peterson et al. (2005), Ragatz et al. (2002), Shen and Yu (2009), Smals and Smits (2012), Wang et al. (2009), Wasti and Liker (1997), Wynstra et al. (2001), Zolghadri et al. (2011), Zsidisin et al. (2004)
7	Modularity	Caridi et al. (2012), Cheng (2011), Danese and Filippini (2010), Dhamus et al. (2001), Droge et al. (2012), Ernst and Kamrad (2000), Fine (2000), Fine et al. (2005), Garg (1999), Krishnan and Ulrich (2001), Lau (2011), Lau and Yam (2005), Lau et al. (2007, 2010), Mikkola and Gassmann (2003), Nepal et al. (2005, 2012), Novak and Eppinger (2001), Parente et al. (2011), Pine et al. (1993), Ramachandran and Krishnan (2008), Ro et al. (2007), Robertson and Ulrich (1988), Salvador et al. (2002), Ulrich (1995), Ulrich and Ellison (1999), van Hoek and Weken (1998)
8	Postponement	Desai et al. (2001), Drejer and Gudmundsson (2002), Huang et al. (2005), Krishnan and Gupta (2001), Labro (2004), Meyer and Dalal (2002), Meyer and Lehnerd (1997), Su et al. (2005), Zhang and Huang (2010)
9	Design for supply chain (DfSC)	Baud-Lavigne et al. (2012), Hilletofth et al. (2010), Lee and Billington (1992), Sharifi et al. (2006)
10	3 D concurrent engineering (3DCE)	Childerhouse et al. (2002), Choi et al. (2001), Christopher and Towill (2001, 2002), Ellarm et al. (2007), Fine (2000), Fine et al. (2005), Fixon (2005), Forza et al. (2005), Kristianto et al. (2012), Kopczak and Johnson (2003), Koufteros et al. (2001, 2005), Peterson et al. (2005), Singhal and Singhal (2002), Thirumalai and Sinha (2005)

2.2.3.1 Match between product design and supply chain: Fisher's model

Fisher (1997) proposed a model describing the types of product (design) and supply chains, and the fit between the two. According to the model, good results can be obtained when functional products are supported by physically efficient supply chains, and innovative products are supplied through market responsive supply chains. The conditions are marked as 'match' in the model. Mismatch between the product type and the type of supply chain can deter performance. Thus an effective supply chain must be designed according to the type of product being supplied. Fisher's model has been tested by many other researchers. It has been supported by Ramdas and Spekman (2000), Childerhouse et al. (2002), Huang et al. (2002), Lee (2002) and Pero et al. (2010). While most firms follow Fishers model, some empirical tests suggest that the model is only partially valid – there do exist two categories of product and supply chains, but the match suggested by Fisher does not always guarantee better performance. When there is a match between product and supply chain, performance is usually better as compared to mismatch, particularly in case of performance indicators such as cost, delivery speed and delivery dependency; but some measures like quality can be achieved with equal level under both match and mismatch conditions (Selldin and Olhager, 2007).

Fisher's model can be widened to consider the aspects of supply chain planning, which becomes more and more complex with increasing product mix and unreliable demand forecasts, especially in case of new and seasonal products. Structural changes in product design affect supply chain dynamics (Verdouw et al., 2010). Successful firms extend the contribution of design to all aspects of their business, by developing a design centric business which facilitates better integration between product design and the supply chain (Khan and Creazza, 2009). In addition to matching product type with supply chain, supply chain planning process must also be differentiated to support the product and the supply chain. As a result of empirical research, Kaipia and Holmström (2007) suggest different supply chain planning approaches for various product types such as efficient replenishment for commodity items, once-off sales planning for seasonal items, streamlined planning for consumer durables, and expert-driven planning for innovative new products. Many a times, instead of only one type of product, big firms offer a variety of both functional and innovative products simultaneously thereby complicating product-supply chain alignment. In such cases, the entire supply chain portfolio must be aligned with the product portfolio, and in some cases, process portfolio. Langenberg et al. (2012) attempted to analyze a firm's optimal supply chain portfolio as a function of its product portfolio, and indicated that alignment of the two could result in tremendous cost savings. More recently, Mansoornejad et al. (2010) developed a design decision making framework, in which product / process portfolio design and supply chain design are linked by design of manufacturing flexibility. They suggest that strategic design of supply chain should reflect product / process portfolio design, and thus SC profit can be considered at an early-stage of design for different product / process portfolios.

2.2.3.2 Rhythm matching

Success of a new product depends not only on its performance, but also on the timing of its entry into the market. Generally NPD efforts for superior product performance take a long time which gives away the competitive advantage to competitors having better time to market capability. An overlapping stage between design and process activities, having interaction among supply chain partners, usually reduces NPD time. One of the biggest challenges in new product development is the tradeoff between speed to market and product performance. Optimal value of the two can be found by matching a firm's technological readiness rhythm with market receptivity rhythm.

The timing of launching a new product must be set according to the receptivity of the market. If the base product performance is low, it should be improved by keeping it longer in development phase, especially if the market window is likely to remain open for a long time. However if the firm possesses strong market power, it should try to launch the product at the earliest, as long as there is no substantial risk of losing market power due to weak product performance (Calantone and Di Benedetto, 2000). Dacko et al. (2008) developed a rhythm matching model and found that in a market imposed situation, firms should adapt their NPD rhythm according to the market receptivity rhythm; while in a firm-imposed situation, firms might have the advantage of driving the market receptivity rhythm. However, in a dynamic situation, things are more complicated because both rhythms influence each other.

Market orientation significantly affects supply chain performance (Lin et al., 2010). During new product diffusion, optimal supply chain configuration should be developed simultaneously along with production and sales plan. Amini and Li (2011) attempted to develop an integrated RM optimization model to provide decisions on the optimal timing to launch a new product, production and sales quantity in each planning period, and safety stock level at each supply chain stage. They suggest that hybrid modeling and solution approach gives better results than non-hybrid alternative modeling approach under various diffusion and supply chain topologies.

Consumers' word-of-mouth (WOM) generally influences the adoption of new products. When the WOM is positive, delayed marketing should be the preferred production / sales policy as it gives the higher expected profit, as well as accommodates well with changes in build-up periods (Amini et al., 2012). The same is more or less also true when WOM is a mix of positive as well as negative. But in case when WOM is only negative, the production-sales policy must be chosen carefully.

2.2.3.3 Extended supply chains

Supply chains have been typically viewed as a network of business processes starting from procurement of raw material, to production of products, their distribution and finally sales to deliver them to the customers. This network can be extended on either side by including product development preceding procurement and recycling succeeding sales. Thus extended supply chains cover the entire product life cycle starting from product development on one end to recycling on the other extreme (Fandel and Stammen, 2004).

The concept of ESC can be useful in long term strategic planning of supply chain network, especially for investment decisions between alternative products by comparing their life cycles with development and recycling costs. However, long and extended supply chains can further increase uncertainties, thus making them more vulnerable to change (Svensson, 2000), and may result in slow growth as compared to integrated supply chains (Lummus and Vokurka, 1999). Existing frameworks revolve mainly around concepts such as lean thinking, rapid replenishment, quick response, decoupling and postponement (Van Hoek et al., 2001; Christopher, 1998; Christopher, 2000; Harrison et al., 1999).

2.2.3.4 Supply chain responsiveness

NPD activities are not only influenced by manufacturing flexibility, but also by the flexibility of inbound and outbound supply chain partners, particularly during increased product proliferation. Malhotra and Mackelprang (2012) observed that simultaneous utilization of both internal (manufacturing) and external (supply chain) flexibilities results in a synergic effect, which can improve the responsiveness of entire supply chain. Under the synergic effect, supply chain flexibility enhances the scope of delivering a flexible response, while internal flexibility increases the chance of achieving the flexible response. The extent of SCR depends upon the type of internal flexibility which is paired with supply chain flexibility. Internal flexibility along with simultaneous design of product and supply chain can facilitate in incorporating agility in a lean supply chain (Ismail and Sharifi, 2006). The result is often referred to as *leagile* supply chain, a combination of lean and agile concepts in which a stable demand before the decoupling point is matched with a lean supply chain and the unpredictable variations downstream are met with an agile supply chain (Naylor et al., 1999; Childerhouse et al., 2002). The decoupling point is the point up to which the supply chain remains lean and after which it becomes agile. It is the point of differentiation between actual and forecasted demand based planning.

Deviations from plan during product development are a point of concern, as corrective actions consume valuable resources and precious development time. Deviations can be reduced significantly through internal alignment, as well as by integrating supply chain partners who can supplement valuable information, knowledge and resources (Koufteros et al., 2010). Internal alignment can be an important driver of supply chain performance, without which all other drivers are of little use (Mentzer, 2004). Most companies lack internal alignment (van Hoek and Mitchell, 2005) which must be improved before going for external integration. When resources are available in plenty, the inter-dependency and thus the need to use them flexibly are usually absent. In case of a resource crunch, firms tend to optimize resources by using them flexibly and with better internal coordination. If the internal alignment permits operational coordination flexibility, it is found to positively influence new product introduction capability of the firm, which in turn varies with resource flexibility in form of an inverse U-shaped curve. However, contradictory to popular belief, resource availability negatively moderates both these relationships (Liu et al., 2009).

New product development and supply chain management can thus be aligned by improving internal alignment, supply chain flexibility, and leveraging of internal and supply chain capabilities to improve supply chain responsiveness (van Hoek and Chapman, 2007).

2.2.3.5 Voice of customer

Designing and managing the supply chain to deliver just what the customer wants is a key to business success (Griffiths and Margetts, 2000; Christopher and Towill, 2001; 2002). Uncertainty of market acceptance can be a major challenge in new product development activity, particularly in case of small and medium enterprises (SMEs), who already have resource limitations in comparison to large organizations (March-Chordà et. al., 2002).

Customer requirements can be collected at the downstream supply chain stages such as retailers and dealers, and passed on upstream to manufacturer and suppliers for product development. Voice of customer can be translated into objectives that unify the entire NPD team across its functional boundaries (Swink, 1998). The involvement of both customer and supplier in new product development are positively influenced by contextual factors such as modular design, product innovation, and internal coordination; and all these lead to better product performance (Lau, 2011). Kano model can be integrated with quality function deployment and service quality (Matzler and Hinterhuber, 1998; Tan and Pawitra, 2001). It may also be used as an effective tool for supply chain market orientation in new product development where good understanding of customer expectations can help supply chain managers to focus on right priorities, and marketing managers to develop promotional material for product features that customers appreciate (Redfern and Davey, 2003). Integration of marketing and manufacturing during various stages of new product development can also be an effective way of capturing VOC and usually results in greater market success, especially in case of innovative products (Song and Swink, 2009).

2.2.3.6 Early Supplier Involvement

Early Supplier Involvement generally refers to a situation when manufacturers involve their suppliers early in the product development process (Bidault et al., 1998). ESI is a means of integrating suppliers' capabilities in the buying firm's supply chain system and operations (Dowlatshahi, 1998). Some of the benefits of involving suppliers in NPD include reduced development cost (Bonaccorsi and Lipparini, 1994), improved performance (Hsuan, 1999), reduced lead-times, and access to supplier's technical expertise and capabilities (Ragatz et al., 2002; Wasti and Liker, 1997). The earlier a supplier is involved in development process, higher is the responsibility delegated to him. However, supplier's involvement during NPD is influenced by the degree of component complexity (Cagli et al., 2012).

Whereas early involvement of suppliers in new product development results in benefits such as reduced cost, shorter time to market, access to expert technical knowledge, improved quality and innovation, etc., but at the same time it increases the risk of leaking propriety knowledge to competitors. Creation of global supply chains (Peck, 2005) and outsourcing of critical activities such as product design further increase the risk of failure. The problem may be reduced to some extent through a formal supplier approval process (Mikkola and Skjøtt-Larsen, 2006), or by perceiving suppliers as co-design partners to manage supply risk (Zsidisin et al., 2004). Such partnerships are mutually beneficial in long run, but call for some investment during initial phase. Lettice et al. (2010) observed that after entering into formal agreement, suppliers tend to increase their level of investment into the partnership, almost matching the expectation of focal firms. The focal firm however, initially invests high in the partnership, but contrary to suppliers' expectations, tends to reduce its share gradually over a period of time. Suppliers also expect some value addition in return to their investment in the firm's innovative efforts. The value can be direct in terms of financial compensation of product development work, as well as indirect, in form of gain of technological knowledge and product designs which can be used for other customers (Smals and Smits, 2012). For most suppliers, the indirect value seems to be of strategic importance and offers opportunities for diversification and expansion of their customer portfolio, while direct value mainly defines the attractiveness of the existing customer portfolio.

Too much integration of suppliers may have a negative effect on new product development, and this relationship can be further negatively moderated by cultural distance between the focal firm and its suppliers (Parente et al., 2011). There may also be some problems that the firms face in managing the involvement of suppliers (Wynstra et al., 2001). Most of these problems arise due to lack of communication and trust, supplier's poor technical capabilities (Wasti and Liker, 1997), limited commitment of suppliers (McCutcheon et al., 1997), and the substantial investment of time and resources required to develop and manage business relationships with suppliers (Petersen et al., 2005). Sometimes intense competition amongst suppliers may also adversely affect the communication and coordination, leading to problems in assigning clear roles during new product development projects (Anderson and Drejer, 2009). Such issues must be resolved carefully while planning the level of supplier involvement.

Both strategic and operational factors must be considered simultaneously while making supplier-selection decision during initial stage of new product development. For example, Khan et al. (2008) examined the role of design variables on risk and developed a framework for design–led supply chain risk management to recognize design as a platform to manage risk of failure. Shen and Yu (2009) have blended individual strategic and operational factors using fuzzy approach to develop a total score of each supplier, which can be used to identify the best potential supplier(s) during NPD. Firms may develop their own procedures for measuring performance of suppliers, but this assessment must conform to the product development strategy of the focal company (Wang et al., 2009).

2.2.3.7 Modularity

In response to varying customer preferences and fast changing product life cycles, successful manufacturers have developed new products more frequently to keep pace with dynamic business environment (Lau and Yam, 2005). Modularity is a strategic design option to increase product variety without proportionately affecting production cost (Salvador et al., 2002; Pine et al., 1993). The product is divided into independent, inter-changeable sub-systems called 'modules' and well-specified interfaces, which can be assembled in a number of combinations. New products may thus frequently be launched by combining and interchanging different qualified modules from among the existing designs, within a short lead time (Ulrich, 1995). The modules are generally made from standardized components which can be manufactured by mass production, keeping the unit cost low. It has been reported that Volkswagen saved about $ 1.7 billion annually on product development and manufacturing cost, as a result of modularization strategy (Dahmus et al., 2001).

Time and performance of new product development activities can be improved by modularity (Nepal et al., 2005), which may be positively moderated by inter-functional integration (Danese and Filippini, 2010). However, cultural distance between the firm and its suppliers negatively moderates the relationship (Parente et al., 2011). The degree of modularity affects the decisions to make-or-buy (Robertson and Ulrich, 1998; Garg, 1999; Ulrich and Ellison, 1999; Krishnan and Ulrich, 2001). Greater degree of modularity has a positive impact on capacity utilization, return on investment, efficiency and thus profitability, but is found to have a negative effect on product specialization (Cheng, 2011).

Rapid improvements in technology enable firms to develop new products and / or upgrade their previous versions at a fast rate, with the objective of attracting new customers. However, existing customers may react adversely since their product becomes obsolete very quickly. Also some new potential customers may defer their purchase, in order to wait for a coming update or a price reduction. The problem can be overcome by providing upgrades in form of upgradable modules. Modular upgradability can be used as a strategic option for keeping a fast pace of innovation, to attract new as well as existing customers, especially in case of technology-oriented rapidly improving products (Ramachandran and Krishnan, 2008).

Modularity affects supply chain design and coordination (Van Hoek and Weken, 1998), adding at least one more level in the supply chain, and permits larger distance among various stages in comparison to integrated product architecture. It requires a lesser degree of supply chain coordination (Lau et al., 2010). Modular products can be best supplied by 'modular supply chains' which permit greater autonomy and lower proximity among module suppliers along with reduced efforts on iterative communication and coordination (Ulrich and Eppinger, 2000). However for innovative products, modularization should be combined with a close supply chain design and high degree of coordination, which gives fascinating results such as reduced inventory, improved quality and reduced lead time (Lau and Yam, 2005). Supply chain design is influenced by a combination of product design features like levels of complexity, modularity and innovativeness. Pero et al. (2010) developed a framework for alignment of new product development and supply chain management. They suggest that key product features such as variety, modularity, and innovativeness, and supply chain variables like configuration, collaboration, and coordination complexities are important for alignment. The level of vertical integration of production is positively correlated to the degree of complexity in product design.

In-house production is considered to be a more attractive option for parts having complex design because greater skills and coordination are needed; while simple components can generally be outsourced for exploiting the benefits of cost reduction (Novak and Eppinger, 2001). Caridi et al. (2012) linked product modularity and innovativeness to supply chain management, and found that breakthrough (high modular – highly innovative) products can be best supplied by collaboration based networks, whereas integrated low-collaborative networks should be preferred in case of derivative (high modular – low innovative) products. Similarly, platform (low modular – highly innovative) products may be better developed using integrated supply chains, while the production of low modular – less innovative products can easily be outsourced. Therefore, both modularity and innovativeness must be considered together when designing the supply chain.

Integrating modular product design with supply chain design and coordination not only saves overall production cost (Ernst and Kamrad, 2000; Mikkola and Gassman, 2003), but may also offer mass customization. However, most firms use modularity mainly for cost reduction, and its potential for achieving mass customization is largely under-explored (Ro et al., 2007). Only a few empirical researches have focused on the integration of product modularization with supply chain design and coordination (Salvador et al., 2002; Krishnan and Ulrich, 2001) to optimize both operational and supply chain performance. Lau (2011) addressed the issues of management of modular product design across the supply chain, and identified some critical factors such as pre-defined product advantage, selectively used design rules, module definition, system integration, technological newness, internal communication, and supplier and customer involvement.

Fine (1998) suggests that apart from cutting production cost, modularity also improves supply chain performance. Modularity is influenced by the degree of supply chain product co-development (SCPC) and improves flexibility and customer service and in turn product performance (Lau et al., 2007). Nepal et al. (2012) developed a multi-objective optimization framework for matching product architecture strategy with supply chain design by incorporating compatibility amongst supply chain partners. They found that modularity increases the number of nodes and hence flexibility of the supply chain; at the same time it also increases the degree of dependency between supply chain partners, thus necessitating higher compatibility amongst them. Thus higher flexibility and compatibility provide the opportunity to outsource some proportion of production, resulting in reduced cost and / or manufacturing lead time, and thus improving the overall supply chain efficiency. Greater outsourcing also results in consolidation of tier-one suppliers into tier-two suppliers having more bargaining power, and often leading to formation of strategic alliances between OEM's and their suppliers.

According to Droge et al. (2012), modularity influences service performance of the supply chain in terms of support performance and delivery performance. In general, product modularity has a positive effect on the support performance as well as on the delivery performance, whereas process modularity positively affects the delivery performance only. Both product modularity and process modularity are positively related to the level of customer integration and supplier integration. Unlike modular products, modular processes lack interfaces and thus require higher level of customer and / or supplier integration to compensate for interfacing.

2.2.3.8 Postponement

Another possible way of offering high variety of design variants and keeping the costs under control is through postponement. Products can be developed using *platform*, a common structure comprising of a set of components and subsystem shared across a product-family, from which many derivatives of the product can be developed (Meyer and Lehnerd, 1997; Krishnan and Gupta, 2001; Meyer and Dalal, 2002). Postponement can then be used as a strategic option to increase product variety without affecting cost. Postponement structures affect supply chain performance in terms of costs and customer waiting times. The choice of supply chain structure varies with product design and manufacturing process. Time postponement supply chain structure fits make-to-order environment, while form postponement supply chain structure is more suitable for the hybrid make-to-stock – make-to-order environment (Su et al., 2005).

Postponement has an important impact on product architecture and degree of modularity. It involves selection of the core technologies and processes to match the product architecture strategy. It affects a tradeoff between the degree of standardization and customization to plan and configure a product platform from which product families may be developed to serve a spectrum of market segments. Developing multiple products simultaneously may to some extent, fulfil both the objectives of mass customization as well as standardization of product platform internally (Drejer and Gudmundsson, 2002). However, postponement may not always turn out to be appropriate for offering extreme levels of market diversity (Krishnan and Gupta, 2001). Platforms having a high degree of component commonality can be effective in reducing manufacturing cost, but at the same time, may also restrict product differentiation and hence revenue. Total manufacturing cost generally decreases with increasing commonality, but this may not always be true (Labro, 2004). There may be an influence of the average quality level of the product range, for example, when high-quality components are made common, the average quality level of the products offered increases (Desai et al., 2001) thereby increasing cost. Postponement, with or without platform commonality, influences supply chain configuration and consequently its performance, resulting in cost benefits due to reduced inventory levels and lesser capability requirements at various stages across the supply chain. However, the effect on time–to–market may be insignificant (Huang et al., 2005). The degree of early supplier involvement (ESI) is also related to postponement. When the suppliers are cooperative, postponement can be made more effective by using a lot-for-lot policy and the supply chain can be made more competitive by offering wider product range (Zhang and Huang, 2010).

2.2.3.9 Design for Supply Chain

Generally the NPD team wants to develop the *best design* that would maximize demand of the product. They usually start with identifying various product features that would appeal to more and more customers. These features are often categorized as qualifiers, winners and delighters (Kano model, 1984), and the resulting initial concept of the product design is often quite ambitious. On the other hand, supply chain managers want a design that results in minimum manufacturing and logistics costs. These different objectives may often lead to conflicts and clashes between NPD and supply chain issues, frequently resulting in trade-off situations. For example, there may be cases when after great time & effort, NPD team comes out with its best design, but it may be difficult to manufacture and / or supply such product through the existing supply chain. Thus some of features from the best design have to be dropped due to resource constraints and capability limitations. Significant effort, time, and cost may thus go waste on features which ultimately have to be dropped.

Better results can be obtained if both NPD and SCM issues are aligned. Lee and Billington (1992) extended the concept of design for manufacturability (DFM) to the entire supply chain, and coined the term Design for Supply Chain (DfSC), which calls for simultaneous design of the product as well as its supply chain. In this approach, NPD process starts from a set of feasible product features which can be delivered by the existing supply chain. Subsequently, more and more features are added one at a time from the market specified list according to the Kano model, only if they can be manufactured and supplied by the existing supply chain. Simultaneous efforts are also made to improve the existing supply chain capabilities through collaboration with existing / new suppliers to accommodate maximum product features. Thus there is no wasteful activity. Another advantage is that the product is viable at any stage of the product design process which may be continued till time and cost constraints permit (Sharifi et al., 2006).

The DfSC approach enables the supply chain to respond quickly to emerging opportunities. Furthermore, it facilitates the introduction of practices such as common product platform across the multiple products, modularity, product / component re-use, and design outsourcing.

2.2.3.10 Three dimensional concurrent engineering

The concept of three–dimensional concurrent engineering was coined by Fine (1998), who suggested adding supply chain as the third dimension to the already established two dimensions of concurrent engineering – product design and process design. The approach calls for simultaneous design of product, process and supply chain, which generally results in better performance.

The 3DCE model (Fine, 1998) suggests involving upstream and downstream supply chain members in the early stages of product development through early supplier involvement and voice of customer. 3DCE calls for participation of customers and suppliers with internal functions for improving performance. The involvement generally results in improved financial performance (Petersen et al., 2005) and cost minimization (Kopczak and Johnson's, 2003) for competitive advantage. Ellarm et al. (2007) advocate 3DCE as a theoretical lens to develop a systemic view of supply chain and organizational performance.

Most literature on the subject addresses linkage between any two dimensions with a mere mention of the third (Koufteros et al., 2001; 2005; Childerhouse et al., 2002; Choi et al., 2001; Christopher and Towill 2001, 2002). Only a few researchers have attempted to explore linkages that are common across all three dimensions. Some significant works in 3DCE include – use of component compatibility (Singhal and Singhal, 2002; Fixon, 2005) and assessment of product architecture (Fixon, 2005) as a tool to link product, process and supply chain design decisions; trade-off between modular and integral design using goal programming (Fine et al., 2005); study of effect of stage of ESI (early v/s late) and level of responsibility given to suppliers on NPD effectiveness through multiple regression analysis (Petersen et al., 2005); etc.

In a critical review of literature, Forza et al. (2005) highlight the strategic issues related to 3DCE such as : why and by what mechanisms should product design, manufacturing process design and supply chain decisions be coordinated; and what are the resulting performance implications? Types of product and supply chain design have direct effect on customer satisfaction. For instance, Thirumalai and Sinha (2005) report that in case of supply chains using internet in the order fulfilment process, customer satisfaction is significantly lower for specialty goods than for convenience goods or shopping goods; thus calling for more attention and resources for design of such supply chains. Kristianto et al. (2012) studied the effect of uncertain customer demand, production and supply lead times and tried to develop an optimum supply chain network by incorporating manufacturing and product design into logistic design. In their model, backorders and inventory level were used as performance measures, and results showed that fewer stockholding points, lower safety stocks and a shorter review period of demand indicate better performance.

From the literature review, it is quite evident that both new product development and supply chain activities play important roles in commercialization of a product, and therefore both of these issues must be addressed simultaneously (Hilletofth et al., 2010). In fact, in a study of the impact of product design on the structure of supply chain, Baud-Lavigne et al. (2012) demonstrate that solving the interdependent problems of product design and supply chain design separately could result in a suboptimal, or even a bad decision. The ten linkages discussed above help in aligning new product development and supply chain management activities, and this alignment is perceived to improve the overall competitiveness.

2.3 Competitive Advantage

Competitive advantage is the degree to which an organization / supply chain can be considered better than its competitors. It is a measure of effectiveness / efficiency relative to competitors, in achieving objectives of sales, market shares, or profitability (Lall, 2001). Firms having higher level of competitiveness are usually more successful than their rival companies, and thus competitiveness can be considered as an important factor for success or failure of any organization / supply chain.

In early days competitive advantage involved selection of market(s) in which an organization would compete, and defending market share in clearly identified segments using price and product performance attributes (Day, 1994). Today it is the firm’s ability to anticipate and quickly respond to dynamically changing market needs (Stalk et al., 1992) through superior competencies of creating value to improve / maintain performance in terms of profitability and market share (Coyne, 1986; Prahalad and Hamel, 1990; Barney, 1991). Competitive advantage is sometimes evaluated as a firm's ability to maintain a defensible position over the competition (Li et al., 2006). In order to sustain competitive advantage, firms have to make continuous improvement in their competencies, or make efforts to prevent imitation by setting up barriers (Day and Wensley, 1988).

Competitive advantage is a multidimensional concept (Narayana, 2004). It is evaluated in terms of relative performance of various dimensions associated with business activity. These dimensions are sometimes referred to as performance measures / indicators, distinctive competencies, critical success factors, competitive priorities, determinants of competitiveness, etc. Competitive advantage comprises of these distinctive competencies that set an organization ahead of its competitors, thus providing an edge in the marketplace (Tracey et al., 1999). Classical determinants of competitiveness focus more on operational efficiency rather than financial performance. Whereas there are many such performance measures, operations management literature widely recognizes five major competitive priorities -- cost, quality, delivery, flexibility, and innovation as critical to operational success of any organization / supply chain (Wheelwright, 1978; Skinner, 1985; Roth and Miller, 1990; Porter, 1991; Fawcett and Smith, 1995; Bagchi, 1996; White, 1996; Koufteros et al., 1997; Boyer and Lewis, 2002; Tracey et al., 1999; Ho, et al. 2002). These five performance measures have been widely accepted as the most important dimensions of competitiveness. Table 2.3 summarizes the literature reviewed related to these dimensions of competitive advantage.

TABLE 2.3: Dimensions of Competitive advantage

S.no..	Dimensions	Authors
1	Cost	Li et al. (2006), Beamon (1999), Balakrishnan et al. (2007), Ark et al. (2008), Majumdar (2010), Olson and Xie (2010), Romano (2002), Zhao and White (2010), Singh (2010), Singh et al. (2010), Nayak and Ray (2010).
2	Quality	Chase and Aquilano (1992), Koufteros (1995), Filson (2002), Chen et al. (2009), Govindan et al. (2010), Zhao and White (2010).
3	Delivery	Li et al. (2006), Gunasekaran et al. (2004), Vastag and Montabon (2001), Sugimori et al. (1997), Narasimhan and Jayaram (1998), Bhatnagar and Sohal (2005).
4	Flexibility	Prater et al. (2001), Sanchez and Perez (2005), Bruce (1985), Nyman (2004), Gunasekaran et al. (2008), More and Babu (2009), Slack (2005), Sangwan Digalwar (2008), Nayak and Ray (2010), Choi and Hartley (1996), Gupta and Al-Turki (1997), Song and Chatterjee (2010), Swafford et al. (2006), Dixon (1992), Jack and Raturi (2002), Upton (1994, 1997), Kara et al. (2002).
5	Innovation	Koufteros (1995), Sen and Egelhoff (2000), Sanchez and Perez (2005), Singh et al. (2007), Roger (1998), Parhi (2010), Majumdar (2010), Mishra and Sahay (2010), Song and Chatterjee (2010), Tapan et al. (2010), Biggs and Raturi (1997), Freeman (1994), Boyer and Lewis (2002), Chan (2003).

2.3.1 Cost

Cost is considered as the simplest measure of competitive advantage. Price / Cost as a competitive priority indicates the ability of a firm to compete against major competitors based on low price (Li et al., 2006). Among various components of cost, those considered important for performance measurement include manufacturing cost, labour cost, raw material cost, R&D cost, facility cost, logistics cost, distribution cost, administration cost, and cost of inventory (Beamon, 1999; Balakrishnan, et.al., 2007; Ark et al., 2008; Majumdar, 2010). In order to gain competitive advantage, global supply chains have set up their production facilities in Asian countries having low cost of labour, warehouses in Middle-East and Latin America to serve high paying European and American markets. Inventory cost has a prominent influence on manufacturing based industries (Beamon, 1999). Inventory cost can be minimized by keeping track on lead time, risk of stock out, and fill rate (Olson and Xie, 2010). With expanding business boundaries, distribution cost has become a major concern for supply chain managers (Beamon, 1999). It can be controlled by optimizing transportation and storage costs together. Direct and indirect costs are also influenced by parameters such as buyer-supplier relationship, employees' skills and capabilities, well planned scheduling techniques, system flexibility, quality management system, and perfect sourcing and delivery decisions (Romano, 2002; Zhao and White, 2010; Singh, 2010; Singh et. al., 2010; Nayak and Ray, 2010).

2.3.2 Quality

Quality has been defined by many researchers differently --- conformance to requirements (Crosby), fitness for use (Juran), customer satisfaction (Drucker), loss a product imposes on society due to poor quality (Taguchi), number of defects per million (six sigma), etc. From competitiveness point of view, quality can be considered as ability of a firm to offer product quality and performance that creates higher value for customers (Koufteros, 1995). Product quality can be perceived in terms of quality of design and the quality of conformance to that design (Chase and Aquilano, 1992). Quality also influences competitive advantage through various indirect factors such as defect free products, better goodwill and stronger brand loyalty, lower marketing cost, less vulnerability to price wars, and ability to command premium prices.

Quality levels are increasing day by day due to rapid advancements in technology, especially in industries such as automobile (Filson, 2002). A study of Taiwanese automotive industry reports that high quality control using six sigma approaches can lead to better customer satisfaction (Chen, et al., 2009). An earlier research on Indian automotive supply chain shows that proper selection of quality parameters during supplier selection process can result in improved profitability, as well as responsiveness of the entire supply chain (Govindan, et al., 2010).

Conformance to quality norms and standards usually influences long- term buyer-supplier relationships and improves financial performance (Zhao and White, 2010).

2.3.3 Delivery

Towards the end of last century, cost and quality had become order qualifiers rather than order winners. Organizations thus started searching for newer ways of gaining competitive advantage. The emerging trend of supply chains made the business environment more complex, often calling for dynamically changing schedules. In such scenario, dependable and timely delivery emerged as the new tool for gaining competitive advantage. Today, delivery is considered an important performance indicator in almost all business activities ranging from raw material procurement to distribution of finished goods. Dependable delivery can be defined as an organization's ability to provide on time, the type and volume of product required by customer (Li et al., 2006). It is an indicator of how much a company honours its own commitment of supplying within due dates.

Including delivery decisions in supply chain strategy generally leads to both strategic as well as operational competitiveness. Delivery capability is affected by factors such as delivery speed, delivery due-date and time (Gunasekaran et al., 2004), flexibility, inventory and the level of customer service (Vastag and Montabon, 2001). For example in automotive manufacturing firms, parameters of delivery usually influence setup time, production scheduling, preventive maintenance, and Kanban (Sugimori et al., 1997). Delivery competitiveness generally increases with buyer / supplier proximity (Narasimhan and Jayaram, 1998; Bhatnagar and Sohal, 2005). It is also affected by other factors such as infrastructural facilities, means of transportation, and location of warehouses.

2.3.4 Flexibility

Flexibility is the capability of an organization to quickly and successfully adapt its process to variations in product design / volume. It allows firms to dampen uneven fluctuations in business environment (Upton, 1997; Prater et al., 2001; Sanchez and Perez, 2005). It also improves SC agility, demand fulfilment and customer satisfaction (Bruce, 1985; Nyman, 2004; Gunasekaran et al., 2008; More and Babu, 2009). Flexibility has been categorized into many dimensions, such as -- product-mix flexibility, volume-based flexibility, process-based flexibility, delivery flexibility, logistic flexibility, and distribution flexibility (Slack 2005; Sangwan and Digalwar, 2008). Product mix and volume are two important elements of flexibility, and usually influence other competitive dimensions such as cost, quality, and delivery (Sangwan and Digalwar, 2008). Volume flexibility improves business performance of suppliers (Nayak and Ray, 2010), and thus acts as an important decision variable in supplier selection (Choi and Hartley, 1996). Flexibility in procurement / sourcing and production affects inventory control decisions, particularly in lean / JIT supply chains (Choi and Hartley, 1996; Gupta and Al - Turki, 1997). It also influences SC agility (Swafford et al., 2006), and improves competitiveness, especially in terms of delivery and volume (Dixon, 1992; Choi and Hartley 1996; Jack and Raturi, 2002).

The type of flexibility which would best enhance competitiveness of firm depends on the type of industry, its goals and objectives, and available resources. Flexibility is an important determinant of competitiveness in automotive sector (Sanchez and Perez, 2005; Sangwan and Dilagwar, 2008; Song and Chatterjee, 2010). Increased flexibility in business operations generally increases overall cost and effort, but at the same time, permits organizations to capture global opportunities (Upton, 1994; Kara et al., 2002). It also helps a company in achieving its objectives of profitable growth and increased market share (Gunasekaran et al., 2008; More and Babu, 2009), as well as improves its ability to incorporate changes required for overall business success.

2.3.5 Innovation

Innovation is the ability of an organization to introduce new products and features in the market place (Koufteros, 1995). It enhances the product development process, and helps in shortening cycle time and lead time (Sen and Egelhoff, 2000). Through innovation, companies can reduce total manufacturing cost, as well as improve upon revenue growth, market capitalization, profit margin, delivery, and flexibility (Sanchez and Perez, 2005; Singh et al., 2007). Firms can also reap the benefits of innovation through patents, copy rights, trademarks and intellectual property rights (Roger, 1998; Singh et al., 2007).

Technology and innovation generally lead to long term business sustainability and global competitiveness (Parhi, 2010). Studies on Chinese and Indian automobile industry highlight the need for regular technology up-gradation and continuous innovation (Majumdar, 2010; Mishra and Sahay, 2010; Song and Chatterjee, 2010; Tapan et. al., 2010). Another work on Italian industries suggests technology as a critical element of sustainable competitive advantage (Biggs and Raturi, 1997). Whereas technology does not directly influence competitiveness, it is a big enabler of innovation, which in turn improves competitive advantage (Roger, 1998). Rapid improvements in technology pave the way for increased rate of innovation in manufacturing process as well as product design. Both product innovation and process innovation contribute in improving competitiveness (Freeman, 1994).

Competitive advantage is not confined only to the five dimensions discussed above. There are numerous other factors that may be used by companies to gain competitive advantage over rivals. Organizations that compete solely on only one of the dimensions of cost, quality, delivery, flexibility and innovation are at a risk of losing the competitive advantage. In fact competitive priorities vary according to the business conditions in which a firm operates. Often it involves trade-off among various priorities in order to achieve long term business objectives (Boyer and Lewis, 2002; Chan, 2003; Singh et al., 2007). In order to achieve long term sustainable competitive advantage, organizations must select their competitive priorities that are complementary to each other and match the firm's operations strategy.

2.4 Analytic network process

Modern business environment is a dynamically changing scenario, full of complexities. The objectives and constraints frequently change with time and usually involve trade-off among various parameters, thereby generating multiple solutions to any business problem. Each solution gives best result in a particular set of conditions. However, multiple solutions can lead to increased complexity while making decision due to lack of prioritization of various options. It may be risky to ignore any significant information, as well as difficult to handle excessive data. Thus selection of a decision making technique that clearly prioritizes various solutions is important for success of any business.

Operations management literature classifies various techniques for solving multi-attribute problems in two main categories (Hwang and Yoon, 1981). These two categories are--- Multiple Criteria Decision Making technique (MCDM) and Multiple Objective Decision Making (MODM) techniques. The former deals with problems having predetermined alternatives; while the latter is suitable for finding optimum solution under a set of inter-acting constraints. For most real life problems, multi criteria techniques are used as tool by decision makers in selecting priorities while choosing preferred solution from amongst various available alternatives (Pohekar and Ramachandran, 2004; Mahalik, 2011). These techniques facilitate decision makers to choose alternatives with highest preference rating. MCDM techniques have been applied in many areas such as business management, economics, energy, engineering, information processing, mathematics, resource channelization, and software development.

Some of the important MCDM techniques include Analytic Hierarchy Process (Saaty, 1980), Analytic Network Process (Saaty, 1996), Data Envelopment Analysis (Charnes et al., 1978), GRA (Deng, 1989), ELECTRE, PROMETHEE (Brans et al.,1986), Rough Set Approach (Pawlak, 1982), and Superiority and Inferiority Ranking Method (Xu, 2001). Each of these methods is based on a unique approach for selection of best alternatives among the feasible ones. Choice of the method to be applied depends on the nature of the problem, user's understanding, and type of data available.

Out of the above mentioned MCDM techniques, Analytic Hierarchy Process (AHP) is one of the most widely used techniques, in which a complex problem is decomposed into a hierarchical model. Elements at one hierarchical level are compared with each other for decision criteria elements at higher hierarchical level to give priorities amongst each set of alternatives. AHP finds its application in areas such as performance evaluation, prioritizing software requirement, vendor selection, etc. (Karlsson et al., 1998; Kumar, et al., 2009; Yang and Shi, 2002). However, a limitation of AHP is that in its comparative judgment process, it fails to capture the inter-dependence among elements at the same hierarchical level (Navarro et al., 2008). In most real life business situations, business elements at the same hierarchical level influence each other. Also, the relationships between various elements may not strictly follow a hierarchical form, where the lower level is dependent on the upper one (Saaty, 1996). In fact the dependence among elements can be multidirectional --- upward, downward, horizontal, across the factors in diagonal or nonlinear fashion, etc. --- more in form of a network rather than a hierarchy. To overcome these limitations, ANP was introduced in 1996 by Thomas Saaty, who had earlier developed AHP. As defined by Saaty (1996), "ANP is a theory of measurement generally applied to the dominance of influence among several stakeholders, or alternatives with respect to an attribute or a criterion." The technique graphically represents the inter-relationships among business elements in form of a loose network, thereby allowing multi-directional flow of dependence in all directions. It includes inter-dependence among elements at same or different levels without necessitating any assumptions about hierarchical and non hierarchical structures. Pair-wise comparisons are made between all the elements, two at a time, which represent the relative influence of the elements with respect to any control criterion. ANP allows prioritization of various elements through simple matrix computations that can easily be performed using any mathematical software. Applications of ANP are found in abundance in existing literature. Some of the major fields include e-commerce strategy selection (Raisinghani et al., 2007), hospitality (Niemira and Saaty, 2004), infrastructure development (Aragones-Beltran et al., 2008; Navarro et al., 2008), logistics (Partovi and Corredoira, 2002), manufacturing system (Ucal and Oztaysi, 2009), supply Chains (Jharkharia and Shankar 2007; Joshi et al. 2013), political and social events (Cheng and Li, 2005), and transport (Kone and Buke, 2007).

CHAPTER 3

RESEARCH FRAMEWORK

3.1 Introduction

This chapter presents an overview of the research framework developed to capture alignment between new product development and supply chain management activities across various stages of the Indian automotive supply chain, and evaluate its resulting influence on competitive advantage. Literature review presented in the last chapter identifies some linkages between NPD and SCM activities that are perceived to contribute towards improving NPD-SCM alignment. At the same time literature review also indicates few gaps in this direction, which give rise to some research questions. The research gaps and the questions stemming out of them help in defining the objectives of this research. These research gaps, questions and objectives have been presented in section 3.2. A theoretical research framework has been developed to carry out the research, and is discussed in section 3.3. Finally the methodology to carry out research has been described in section 3.4.

3.2 Research gaps, questions and objectives

Literature review has unveiled that research on NPD-SCM alignment is relatively a new concept, with most of the research being carried out in the last decade or so. Studies conducted so far have established numerous performance metrics individually for new product development as well as supply chain management. However, linking NPD and SCM activities is a relatively new research area. Most researchers have focused on testing the effect of few linkages independently, such as early supplier involvement (Petersen et al., 2005; Ragatz et al., 2002), modularity (Salvador et al., 2002; Krishnan and Ulrich, 2001; Lau, 2011; Fine et al., 2005), and postponement (Huang et al., 2005; Desai et al., 2001). It has been noticed during the literature review process, that most of these frameworks have neglected the strategically significant *systems approach*. There is a lack of any integrated framework that measures the impact of plural linkages on NPD-SCM alignment, as well as the influence of NPD-SCM alignment on competitive advantage. This is clear research gap. Also, the prior research has largely assumed these linkages as independent of each other. However, complex interactions among various linkages may affect NPD-SCM alignment and competitiveness of a business organization. The effect of inter-dependence amongst linkages has not been addressed and is another research gap. Different NPD-SCM linkages may be valued differently by various stages of the supply chain. A clear prioritization of linkages in terms of their impact on NPD-SCM alignment has not been considered in past research. Further, hardly any significant work has been carried out in Indian automotive industry which addresses the above issues across the entire supply chain, i.e. includes suppliers, manufacturers, and customers in a single study.

In order to address the above research gaps effectively, some questions need to be answered. Working along these questions helps in maintaining the research focus. For empirical research, these questions are 'what' and 'who', while in case of in-depth case studies, they are 'which', 'how' and 'why' (Wacker, 1998; Stuart et al., 2002). To explore insights into the Indian auto-component industry, the presented research is structured around a few well defined questions. Answers to such questions lead to better understanding of research propositions as well as help in developing managerial implications for the industry. They serve as a great aid in defining the research objectives. Based on addressing the above mentioned research gaps, some research questions and objectives of this research have been clearly defined in context of Indian automotive industry, specifically the fast growing passenger car segment. These research questions and objectives are presented in Table 3.1.

TABLE 3.1: Research questions and objectives

Research questions	Research objectives
What are the key linkages that influence NPD-SCM alignment in Indian automobile industry? Whether any alignment exists between NPD and SCM activities in Indian automobile industry?	To identify the determinants of NPD-SCM alignment in Indian automobile industry. To measure the current level of NPD-SCM alignment in Indian automobile industry.
Do these linkages impact each other while influencing NPD-SCM alignment? What is priority structure among linkages in affecting NPD-SCM alignment? How strong in comparison to established factors, is the impact of NPD-SCM alignment in improving competitive advantage?	To develop an integrated framework that— i) Captures the effect of inter-dependence among linkages, and prioritizes their influence in improving NPD-SCM alignment; ii) Establishes the significance of NPD-SCM alignment in improving competitive advantage, in comparison to established factors such as cost, quality, delivery, flexibility, and innovation.
Do the priority of linkages in influencing NPD-SCM alignment and impact of NPD-SCM alignment on competitive advantage vary across different stages of the Indian automotive supply chain? If yes, what are the reasons for variation across different stages of the Indian automotive supply chain?	Validation of the integrated framework through case studies for industry generalization across Indian automotive industry. Drawing managerial implications through research extension/ refinement to identify the reasons of disparity across different stages of the Indian automotive supply chain.

3.3 Conceptual model

While carrying out any research, it is usually helpful to have a theoretical framework within which to work. Such a framework enables logical predictions to be made about the phenomenon under investigation, and helps to analyze the observed behaviour in lines with the research objectives. The presumed relationship of various linkages on NPD-SCM alignment has been identified through survey of existing literature. The purpose of this research is to identify the linkages that significantly influence NPD-SCM alignment in Indian automotive industry, and to evaluate the impact of NPD-SCM alignment on competitive advantage. A conceptual model has been developed (Figure 3.1) to capture the influence of some key linkages on NPD-SCM alignment, and the impact of NPD-SCM alignment on competitive advantage, in comparison to already established factors such as cost, quality, delivery, flexibility, and innovation.

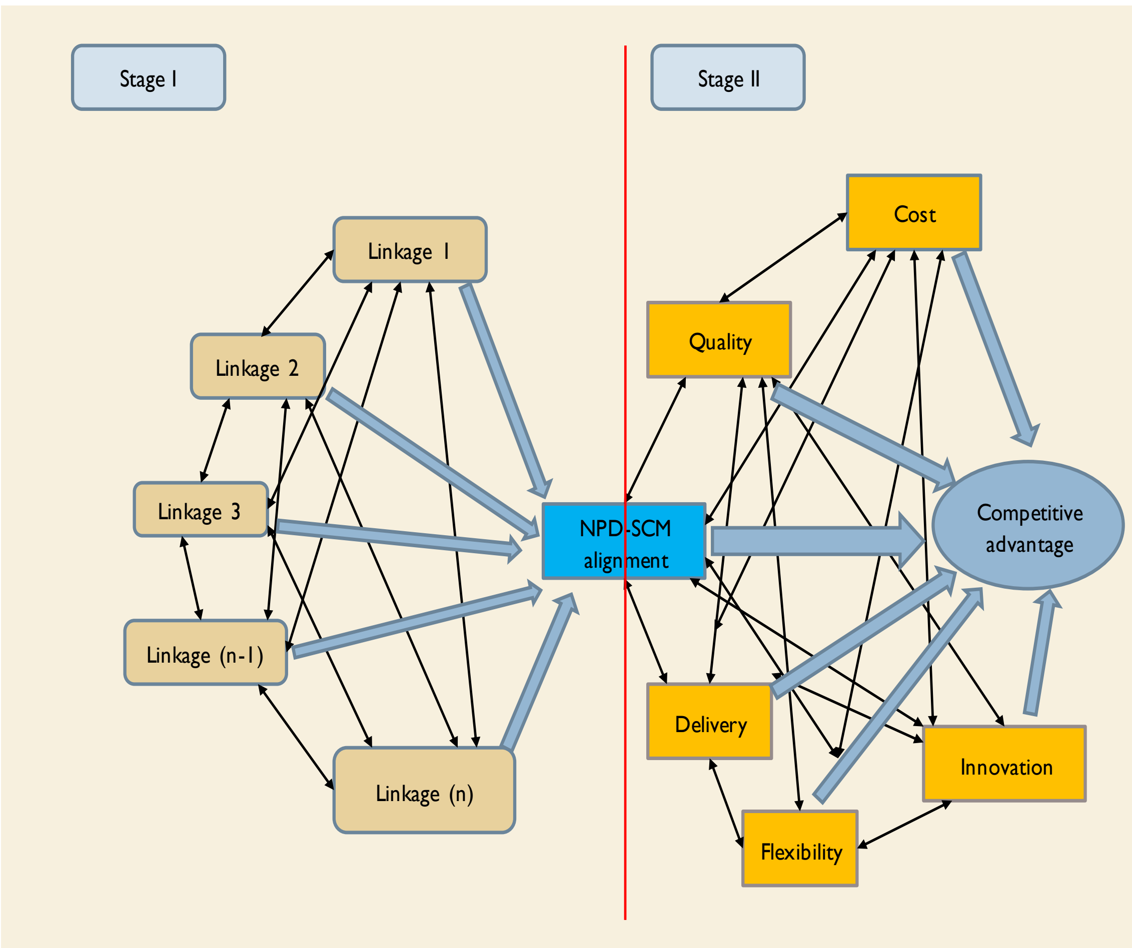

FIGURE 3.1: Conceptual model

The model works in two stages. Stage I measures both direct and indirect influence of various linkages on NPD-SCM alignment. First, the direct influence of various linkages on NPD-

SCM alignment is measured as shown by the thick blue arrows between various linkages and NPD-SCM alignment. While affecting NPD-SCM alignment, it may be possible that some linkages influence each other. For example, linkage 1 may affect NPD-SCM alignment, as well as linkage 2, and linkage 2 influences NPD-SCM alignment. Thus linkage 1 influences NPD-SCM alignment directly, as well as indirectly through linkage 2. Vice-versa can also be true, i.e. linkage 2 may also impact linkage 1, and thus influences NPD-SCM alignment indirectly through linkage 1, in addition to its direct impact. In other words, inter-dependence amongst various linkages may result in indirect influence on NPD-SCM alignment. Therefore, proposed framework must be capable of capturing the inter-dependence among various linkages, and hence their indirect influence on NPD-SCM alignment as well. The inter-dependence amongst linkages has been shown by thin black line arrows in Figure 3.1. Since any given pair of linkages may influence each other, the inter-dependence has been shown by arrow-heads in both directions. In stage II, the model captures the direct influence of various factors (including NPD-SCM alignment) on competitive advantage (shown in Figure 3.1 by the thick blue arrows between various factors and competitiveness); as well as inter-dependence among various factors (shown by thin black line arrows in Figure 3.1), and hence their indirect influence on competitive advantage. Stage I and stage II together integrate both direct and indirect influence of various linkages on NPD-SCM alignment and that of various factors on competitive advantage. Thus the conceptual model addresses the research objectives in a rational way.

3.4 Research Methodology

In order to address the research questions properly, every research must evolve around a carefully chosen research methodology that fulfils the research objectives. Selection of research methodology comprises of choosing the best combination of various alternatives from the three dimensions of the research process, namely - research strategies, research methods, and data type and analysis, according to the type of information needs stemming out from research questions (Taylor et al., 2006). Since this research aims at prioritizing the contribution of some linkages towards NPD-SCM alignment and evaluating the effectiveness of NPD-SCM alignment in improving competitiveness, the required information would largely need quantitative data. Among the different options of research strategy, an approach combining large-scale survey with in-depth case studies has been chosen to fit into the research framework. Whereas a large-scale survey provides inferences for a particular population based on a representative sample, the implications can be generalized only after their validation into the specific environment (McCutcheon and Meredith, 1993). Results of a survey usually provide baseline for longitudinal case studies (Malhotra and Grover, 1998), which can be used to overcome the above mentioned limitation. Case research examines the actual practices in real situations and helps in developing deep understanding of the complexities embedded in the entire phenomena (Bebensat et al., 1987; Ellram, 1996). Since case study is used as a unit of analysis, deep exploratory investigations can be performed on all factors that affect a criterion, along with the environment in which they work (McCutcheon and Meredith, 1993; Yin, 2003). Case research often provides qualitative analysis of the quantitative outcome of survey based researches. Thus, case studies are usually used to validate the findings of a large scale survey, since their inferences can be easily extrapolated to be generalized on a larger scale, for similar populations under the same phenomenon. Therefore, considering above mentioned merits, current research adopts a combination of large scale survey and case research as its research strategy. The research method adopted for large-scale survey is that of questionnaire, which has been administered online using an internet survey portal. Case research has been carried out in form of three longitudinal case studies using questionnaire as well as structured interviews. Since there is a high probability of inter-dependence among variables as perceived from the literature review, analytic network process has been used for data analysis. The ability of ANP to capture the effect of inter-dependence has already been elaborated in literature review. A flowchart depicting the research methodology is shown in Figure 3.2.

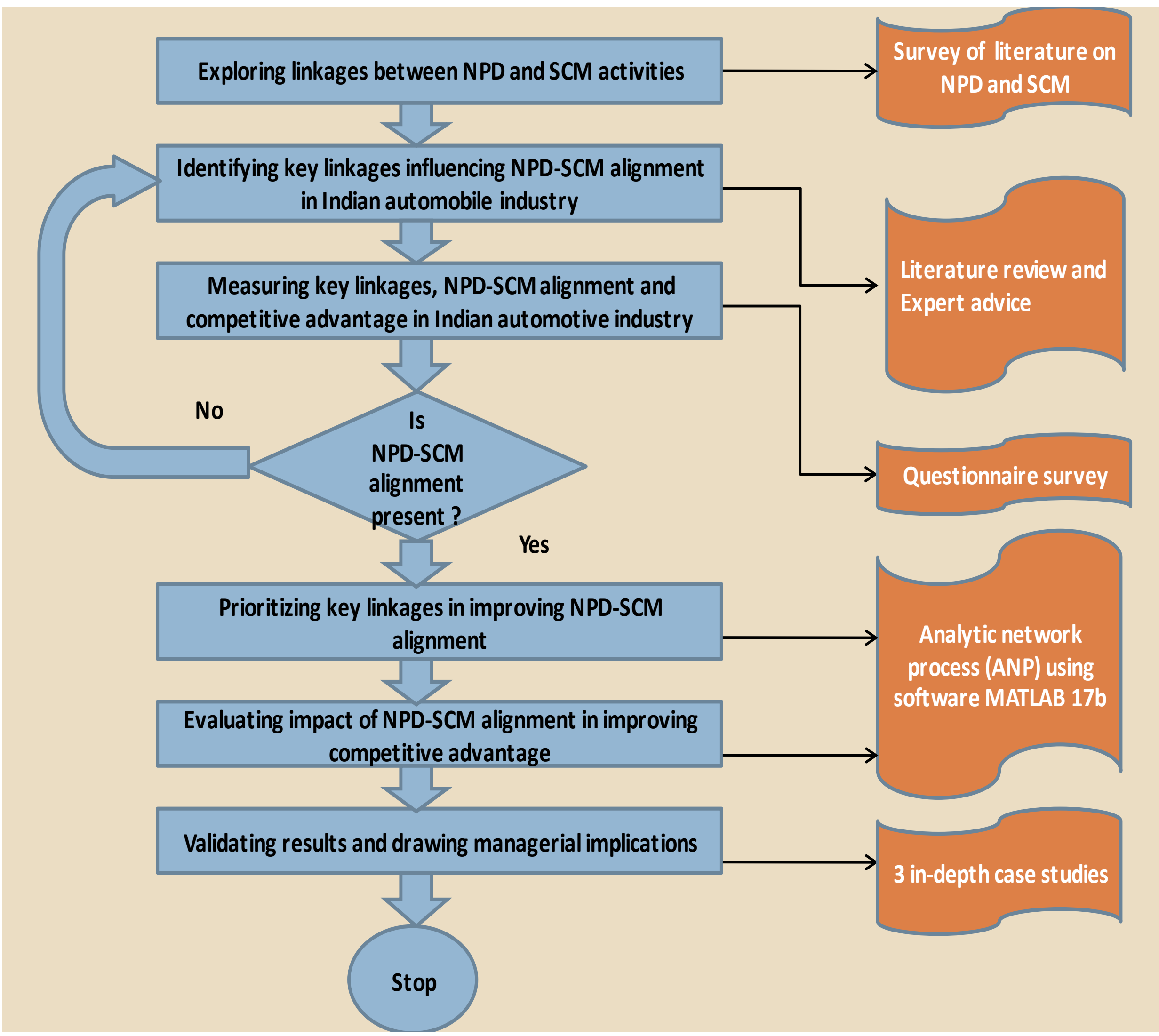

FIGURE 3.2: Research Methodology

The research methodology attempts to address the research questions mentioned in Table 3.1 through various methods / techniques. It comprises of six steps as shown in the blue coloured process boxes in the flowchart. The method / technique adopted for each step has been shown in the orange coloured boxes. A brief explanation of the research methodology is given below:

1. Exploring linkages between NPD and SCM activities

The starting point of the research was to explore all prominent linkages between NPD and SCM activities that contribute towards improving competitive advantage. An extensive literature survey was carried out, details of which have been discussed in chapter 2. Ten prominent linkages between NPD and SCM activities were identified through literature survey, and these are again mentioned below:

i) Match between product design & supply chain

ii) Rhythm matching

iii) Extended supply chains

iv) Supply chain responsiveness

v) Voice of customer

vi) Early supplier involvement

vii) Modularity

viii) Postponement

ix) Design for supply chain

x) Three dimensional concurrent engineering

2. Identifying key linkages influencing NPD-SCM alignment in Indian automobile industry

The first research question seeks to determine key linkages that influence NPD-SCM alignment in Indian automotive industry. The ten linkages mentioned above have been observed in a variety of industries such as manufacturing, electronics, computers, automobiles, textiles, etc. However, it can be argued that not all ten linkages are universally applicable in all types of industries. For example, some of the linkages found between NPD and SCM activities in a particular industry such as electronics may not exist in some other industry such as textiles. In other words, linkages are specific to a particular type of industry. Since a greater number of linkages are expected in case of products that are sensitive to frequent design changes as well as supply costs, the fast growing Indian automation industry has been chosen as the focal area of the study. Therefore, it was required to identify linkages that are present in Indian automobile industry. For this, opinion was sought from ten experts working in the relevant field. Out of these, six were professionals working at senior positions in Indian automobile industry, two at each stage of the supply chain – supplier, manufacturer, and dealer. Remaining four were eminent academicians having research interest in the area of competitiveness of Indian automotive supply chain. The research objectives were explained to them and all the ten linkages were discussed in context of their relevance in Indian automotive industry, with the purpose of developing deeper understanding of the concepts. These discussions turned out to be of great help in refining the objectives, methodology, and scope of the research. Finally, the experts were asked to rate the ten linkages according to their relevance in improving NDP-SCM alignment and competitive advantage in Indian automotive industry. A five point Likert scale was used for rating as shown in Table 3.2.

TABLE 3.2: Likert scale for rating of linkages

Linguistic scale	Indicative meaning
1	To a negligible extent
2	To a small extent
3	To a moderate extent
4	To a considerable extent
5	To a great extent

The ratings given by all the experts to each linkage were averaged. The average ratings of all the linkages are given in Table 3.3. Linkages with average rating of 3 and higher were selected for the research, as they were perceived by the experts to influence NDP-SCM alignment and competitive advantage in Indian automotive industry, at least to a moderate level.

TABLE 3.3: Average of ratings given by experts

Linkage	Average rating
Match between product design & supply chain	2.7
Rhythm matching	2.9
Extended supply chains	1.2
Supply chain responsiveness	3.8
Voice of customer (VOC)	4.6
Early supplier involvement (ESI)	4.7
Modularity	4.4
Postponement	3.9
Design for supply chain (DfSC)	2.5
Three dimensional concurrent engineering (3DCE)	1.8

Thus, the following five linkages out of ten were shortlisted as key linkages:

i) Early supplier involvement

ii) Voice of customer

iii) Modularity

iv) Postponement

v) Supply chain responsiveness

3. **Measuring key linkages, NPD-SCM alignment and competitive advantage in Indian automobile industry**

Second research question enquired whether any alignment exists between NPD and SCM activities. But before evaluating the impact of linkages on NPD-SCM alignment, it was necessary to find out whether the shortlisted key linkages were visible in Indian automobile industry, and how much importance the industry professionals gave to NPD-SCM alignment and competitive advantage. Since the priority of linkages was also to be determined, measurement of existing levels of all the key linkages, NPD-SCM alignment, and competitive advantage in Indian automobile industry would solve both the above objectives. For measuring the existing levels of key linkages, NPD-SCM alignment and competitive advantage, a structured questionnaire was developed to collect information from professionals working at different levels in various companies in Indian automotive supply chain. The questionnaire contained a set of four-five questions for each variable, and respondents were asked to indicate on a five point Likert scale, the extent to which a particular phenomenon was practiced in their organization. The Likert scale used was the same as that used for short-listing of linkages (Table 3.2). The questionnaire was administered online to various professionals working at different levels in various stages of the Indian automotive supply chain, i.e. suppliers, manufacturers, and dealers. The details of the questionnaire survey have been discussed in the next chapter.

The average score of each variable for a particular response gave an indicative measure of the existing level to which the variable was being practiced in that organization. Similarly, averaging across all organizations (responses) resulted in an indicative measure of the existing level to which the variable was visible in the entire Indian automobile industry. In this manner, the existing levels of all the variables, i.e. five key linkages, NPD-SCM alignment, and competitive advantage were measured. The detailed analysis for each variable has been presented in chapter 5 of this thesis.

4. Prioritizing key linkages in improving NPD-SCM alignment

Third and fourth research questions were also addressed with the help of the same questionnaire. For evaluating relative importance, respondents were asked to rate the influence of each linkage in improving NPD-SCM alignment of their firm. To capture the effect of interdependence among linkages, a set of questions were framed. For each linkage respondents were asked to indicate the influence of remaining linkages on it. For example, respondents were asked to indicate the degree to which early supplier involvement is affected by each of the remaining linkages, while influencing NPD-SCM alignment. Similar questions were framed for each of the remaining linkages. Information from these questions was used to form pair-wise comparison matrix for each linkage. The relative importance of all key linkages was calculated in form of priority vectors using ANP. Data analysis and results have been presented in detail in chapter 5.

5. Evaluating impact of NPD-SCM alignment in improving competitive advantage

In order to address fifth research question, the questionnaire included questions that sought information about competitive advantage of the company, and relative contribution of various factors, including NPD-SCM alignment, in influencing competitive advantage. Questions similar to those used for measuring influence of key linkages on NPD-SCM alignment were framed. Similarly, priority vectors for various factors influencing competitiveness were calculated using ANP. Out of these, the priority vector of NPD-SCM alignment indicated the relative impact of NPD-SCM alignment in improving competitive advantage in comparison to other established competitive priorities. The details of analysis and results have been presented in chapter 5.

6. Validating results and drawing managerial implications

In response to sixth and seventh research questions, three longitudinal case studies were undertaken, one each at three different stages of the Indian automotive supply chain, namely – supplier, manufacturer, and dealer (customer). The purpose of these case studies was to validate findings of the questionnaire survey. Several visits were made to the case organizations for detailed study with the aim of developing deeper understanding of the research objectives. Data was collected through structured interviews, as well as, by means of a questionnaire. For consistency, the same questionnaire was used and responses were filled manually after discussing each question. Executives from different job functions having decision-making roles, working at different hierarchy levels and having at least five years of experience in the company were chosen from different job functions, and were interviewed. The purpose of the research was clearly explained to the executives as well as to the top management. An overview of questionnaire was first described before asking questions. Responses were documented manually in already prepared manuscripts. Wherever required, queries were discussed until the question was clearly understood by the executives. Some open ended questions were also discussed in order to explore reasons for the variations in priority of linkages in influencing NPD-SCM alignment, and the impact of NPD-SCM alignment on competitive advantage in the case companies. The case studies have been presented in detail in chapter 6.

3.5 Conclusion

This research is targeted at evaluating the relative importance of key linkages in influencing NPD-SCM alignment, and the priority of NPD-SCM alignment in improving competitiveness of the Indian automotive industry. For this, a research framework has been developed to bridge the gaps observed in current literature and the research questions stemming out of it. Based on these questions, research objectives have been clearly defined, and these have been achieved using an appropriate research methodology that works around a conceptual model designed to capture the contribution of all key linkages on NPD-SCM alignment, and the latter's resulting impact on competitive advantage across various stages of the Indian automotive supply chain. The details of methodology implementing the steps involved, data collection, data analysis, and results are discussed in the succeeding chapters.

CHAPTER 4

DATA COLLECTION

4.1 Introduction

The preceding chapter discussed the entire research framework comprising of research gaps identified from literature review, research questions and objectives, a proposed conceptual model to capture the effect of all variables, and a step by step methodology that would serve as implementation plan to carry out the research. It may be recalled that this research aims to prioritize relative importance of key linkages in influencing NPD-SCM alignment and evaluate the impact of resulting NPD-SCM alignment in improving competitive advantage across various stages of the Indian automotive supply chain. For the purpose, a conceptual framework has been proposed (Figure 3.1) to capture the effect of variables (numbered 1 to n) on NPD-SCM alignment and various factors affecting competitive advantage; and a research methodology has been developed (Figure 3.2) to carry out the research. As a first step of the research methodology, a pool of linkages between new product development and supply chain management activities has been created through an extensive literature survey. Ten prominent linkages have been identified as outcome of the first step. In the second step, short listing of linkages has been done according their relevance to the Indian automobile industry, through expert opinion followed by rating of the linkages. Short listing confined the study to major contributing linkages, and thus helped in focusing the centre of attention to investigate and comprehend the key functional elements. Five linkages have been short listed as key linkages that influence NPD-SCM alignment in Indian automobile industry.

Now that the key linkages have been identified, it would be proper to substitute them in place of linkages 1 to n in the proposed conceptual model. Inserting the names of the identified key linkages not only makes the model clearer and easy to understand, it also helps in implementing subsequent steps of the research methodology. Since the model integrates influence of all the five key linkages on NPD-SCM alignment, and impact of all six factors on competitive advantage, it has been referred to as integrated framework and is shown in Figure 4.1.

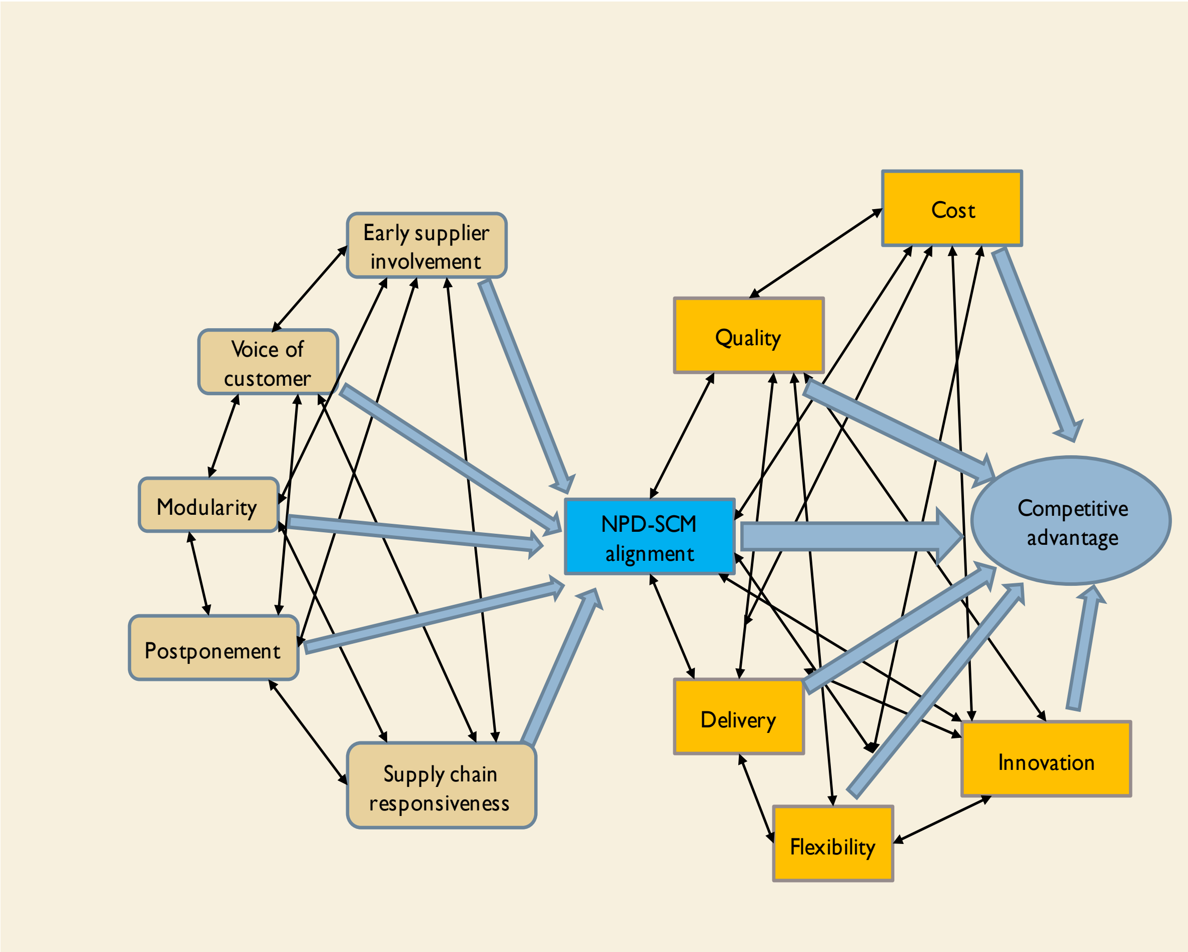

FIGURE 4.1: Integrated framework

The third step of research methodology aimed to measure existing levels of all the key linkages, NPD-SCM alignment, and competitive advantage across the entire Indian automotive supply chain. This has been done through a questionnaire survey, which was administered online to a number of professionals working in various organizations across different stages of the Indian automotive supply chain, i.e. supplier, manufacturer, and dealer (customer). The details of the questionnaire survey have been discussed in the succeeding sections.

4.2 Development of Questionnaire

On basis of the integrated framework and literature review, a questionnaire was designed as an instrument to measure existing levels of all the key linkages, NPD-SCM alignment, and competitive advantage across the entire Indian automotive supply chain. The process of instrument development has been carried out in three stages, as discussed below.

4.2.1 Item generation

The definition of all constructs, i.e. five key linkages, NPD-SCM alignment, and competitive advantage were extracted from literature review. For each construct, a number of potential items were either adopted from previous studies and modified as per need, or generated through review of literature. Instruments for measuring early supplier involvement, voice of customer, modularity, postponement, supply chain responsiveness, and competitive advantage were available in past research (Koufteros, 1995; Tu et al., 2004; Li et al., 2005, 2006; Thatte, 2007; Liao, 2008; Thatte et al., 2013), and hence items from these studies were assorted into an initial pool after making modifications to suit the requirements of the current research. These instruments have already been tested in previous studies and have been found valid and reliable hence there was no further need of testing them again. The construct for NPD-SCM alignment has been developed in this research.

According to Churchill (1979), any measure in an empirical study must ensure content validity, i.e., the items of a construct must cover the entire domain of the construct. Therefore, to ensure content validity, construct for measuring NPD-SCM alignment was developed through an extensive review of literature on linkages between NPD and SCM (Kopczak and Johnson, 2003; Fine et al, 2005; Peterson et al., 2005; Lau and Yam, 2005; Nepal et al., 2005, 2012; Anderson and Drejer, 2009; Liu, 2009; Koufteros, 2010; Lettice et al., 2010; Mansoornejad et al., 2010; Pero et al., 2010; Lau, 2011; Cagli et al., 2012; Caridi et al., 2012; Droge et al., 2012; Langenberg et al., 2012; Malhotra and Mackelprang, 2012). Various items suggestive of NPD-SCM alignment were collected from literature, and a pool of sixteen items was formed. These items can be sub divided into four categories – involving supply chain partners in NPD (3 items), understanding capabilities and constraints of SC members (4 items), clear division of roles and responsibilities among SC members during NPD (3 items), and sharing of cost, resources, benefits, and information among SC members during NPD (6 items). The initial pool of items for all the constructs including NPD-SCM alignment is given in Appendix A.

4.2.2 Short listing of items

The initial pool of items for all the constructs was referred to six practitioners and four academicians for a pre-pilot study, to check the consistency of every item with the definition and content of each construct. The definitions of all the constructs were provided to these persons and their feedback was taken on various issues such as relevance of the questions, specificity, clarity and ease of understanding. Their opinion on the length of the questionnaire was also sought. Based on the feedback from the practitioners and academicians, items were included, modified, combined, or discarded to ensure content validity of the instrument. The definitions of constructs were also modified to ensure that the domain of the construct is fully covered, thus further strengthening content validity. To maintain uniformity, six items were short-listed for each construct as shown in Table 4.1.

TABLE 4.1: Construct items after short-listing

Code	Construct and Items
	Early supplier involvement
ESI 1	We include our key suppliers in our planning and goal-setting activities
ESI 2	Our firms forecasts are coordinated with our suppliers
ESI 3	We and our suppliers share knowledge of core business processes related to each other
ESI 4	We regularly solve problems jointly with our suppliers
ESI 5	We actively involve our key suppliers in new product development processes
ESI 6	Our suppliers keep us fully informed about issues that affect our business
	Voice of customer
VOC 1	We frequently take feedback from our customers
VOC 2	We frequently determine future customer expectations
VOC 3	We include our key customers in our planning and goal-setting activities
VOC 4	We inform our customers in advance of making changes in product design, mix or volume
VOC 5	We and our customers share knowledge of core business processes related to each other
VOC 6	We actively involve our key customers in new product development processes
	Modularity
MOD 1	Our products share common modules
MOD 2	Product modules can be reassembled into different forms
MOD 3	Product feature modules can be added to a standard base unit
MOD 4	Our production process is designed as adjustable modules
MOD 5	Production process modules can be re-sequenced for changing production needs
MOD 6	Our production process can be adjusted by adding new process modules
	Postponement
POS 1	We delay production until customer orders have actually been received
POS 2	We delay final product assembly activities until the last possible position (or nearest to customers) in the supply chain
POS 3	We delay ordering of supplies from suppliers until customer orders have actually been received
POS 4	We delay some form of value-addition to the product until customer orders have actually been received
POS 5	Production process modules can be re-arranged so that customization sub-processes occur last
POS 6	Postponement opportunities are evaluated jointly with key supply chain partners
	Supply chain responsiveness
SCR 1	Our operations / manufacturing system can adjust to changes in product mix / volume demanded by customers
SCR 2	Our operations system rapidly re-allocates people to address demand changes
SCR 3	Our operations system rapidly re-configures equipment to address demand changes
SCR 4	Our operations system effectively expedites emergency customer orders
SCR 5	Our logistics system responds rapidly to unexpected demand change in product mix / volume
SCR 6	Our major suppliers are able to accommodate our request for change product mix / volume in a relatively short time
	NPD-SCM alignment
NSA 1	Our firm has an extensive understanding of our supply chain's constraints / capabilities as they relate to our product development activities
NSA 2	Our firm's key supply chain partners understand how their decisions/actions affect our NPD process

NSA 3	Our new product development goals are framed in consultation with our supply chain partners
NSA 4	Our new product development process involves our key supply chain partners
NSA 5	We and our supply chain partners have clearly defined responsibilities in new product development
NSA 6	Our firm and its key supply chain partners share the costs and benefits of developing new products
Competitive advantage	
CA 1	We are able to offer prices as low or lower than our competitors
CA 2	We offer high quality products to our customers
CA 3	We deliver customer orders on time
CA 4	We alter our product offerings to meet client needs
CA 5	We cater to customer needs for "new" features
CA 6	We have time-to-market lower than industry average

4.2.3 Pilot Study

In order to test reliability of the measurement scale, a pilot study was conducted on a small scale. Reliability refers to the consistency of any research instrument while making measurements (Taylor et al., 2006). It indicates the degree to which repeated measurements under same conditions will give same results (Liao, 2008). A short questionnaire was developed in which for each construct, respondents were asked to indicate on a five point Likert scale the degree to which all the items mentioned in Table 4.1 were being practiced in their organization. For the pilot study, all the six practitioners who had helped in short-listing the linkages and the construct items were requested to help in getting the short questionnaire filled from five executives each from their organizations. As mentioned earlier, these six professionals were working at very senior positions in different automobile companies, two at each stage of the supply chain – supplier, manufacturer, and dealer. They were also well acquainted with the research objectives and the purpose of the questionnaire survey. With their support, a total of 30 responses were received, ten from each stage of the automotive supply chain, i.e. supplier, manufacturer, and dealer (customer).

For testing reliability of the measuring instrument, the commonly used indicator Cronbach's alpha (Cronbach, 1951) was used. For the pilot survey, Cronbach's alpha was calculated using the popular statistical software SPSS 14.0. Items from each construct were deleted one at a time, and values of Cronbach's alpha were calculated. An increase in alpha value indicates that the construct would become more reliable if that item was discarded. A value of alpha more than 0.7 is considered to be an acceptable level of reliability for any construct (Nunally, 1978). Table 4.2 shows the values of Cronbach's alpha for every construct when all items are included, and when each item is deleted one at a time with replacement. An increase in alpha value on deletion of a particular item indicates increase in reliability, and hence suggests that the item must be dropped from the construct. For example, the value of Cronbach's alpha for the construct early supplier development when all six items are included is 0.890. When each of the items is deleted one by one (with replacement), the value of Cronbach's alpha decreases in case of five items, but for the item ESI6, it increases to 0.912. This implies that the reliability of the construct early supplier involvement would increase if the item ESI6 is discarded. Similarly, reliability of some constructs can be increased by deleting items VOC4, POS6, SCR3, NSA2, and CA6 as shown in Table 4.2. In case of the construct for modularity, all the six items are contributing towards improving reliability and deleting any one would result in decrease in the value of Cronbach's alpha, and so none of the items was dropped.

Thus, in order to improve reliability of the measurement scale, one item has been dropped from every construct except modularity.

TABLE 4.2: Reliability analysis of questionnaire items

Construct	Cronbach's alpha	Item	Alpha on deleting item
Early supplier involvement	0.890	ESI 1	0.849
		ESI 2	0.805
		ESI 3	0.798
		ESI 4	0.846
		ESI 5	0.762
		ESI 6*	**0.912**
Voice of customer	0.878	VOC 1	0.780
		VOC 2	0.817
		VOC 3	0.846
		VOC 4*	**0.930**
		VOC 5	0.716
		VOC 6	0.803
Modularity	0.937	MOD 1	0.879
		MOD 2	0.854
		MOD 3	0.912
		MOD 4	0.900
		MOD 5	0.903
		MOD 6	0.887
Postponement	0.860	POS 1	0.831
		POS 2	0.807
		POS 3	0.764
		POS 4	0.796
		POS 5	0.854
		POS 6*	**0.897**
Supply chain responsiveness	0.883	SCR 1	0.869
		SCR 2	0.849
		SCR 3*	**0.922**
		SCR 4	0.795
		SCR 5	0.816
		SCR 6	0.833
NPD-SCM alignment	0.824	NSA 1	0.798
		NSA 2*	**0.866**
		NSA 3	0.762
		NSA 4	0.793
		NSA 5	0.813
		NSA 6	0.807
Competitive advantage	0.916	CA 1	0.884
		CA 2	0.853
		CA 3	0.819
		CA 4	0.897
		CA 5	0.903
		CA 6*	**0.932**

*** Item dropped**

To summarize, the questionnaire has been developed in three stages -- item generation, item short-listing and pilot study, as described above. The items were first assorted through literature review and then filtered at successive stages in order to ensure content validity and reliability, as well as to shorten the length of the instrument. The number of items at different stages of questionnaire development is shown in Table 4.3.

TABLE 4.3: Number of items at different stages of questionnaire development

Construct	Items in initial pool	Items after short-listing	Items after pilot study
Early supplier involvement	11	06	05
Voice of customer	13	06	05
Modularity	08	06	06
Postponement	08	06	05
Supply chain responsiveness	13	06	05
NPD-SCM alignment	16	06	05
Competitive advantage	09	06	05

4.2.4 Questionnaire design

A close ended questionnaire was designed using Likert scale technique of attitude measurement, in which respondents had to express their opinion on the magnitude of various items that were used to measure each construct. For every construct, first the definition of the construct was given, and then the respondents were asked to indicate on a five point Likert scale, the extent to which each item of the construct was being practiced in their organization. A conversion table was also included which translated the Likert scale to a verbal scale for clear understanding of the scale. As an illustrative example, an extract from the questionnaire showing the question for measuring the construct early supplier involvement is shown in Figure

4.2. All the remaining linkages, NPD-SCM alignment and competitive advantage were measured in similar fashion.

Early supplier involvement

Early supplier involvement is the practice of involving key suppliers early in the planning and or product development phase, or while making strategic / major decisions.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

Please select the most appropriate answer.

		1	2	3	4	5
1	We include our key suppliers in our planning and goal-setting activities					
2	Our firms forecasts are coordinated with our suppliers					
3	We and our suppliers share knowledge of core business processes related to each other					
4	We regularly solve problems jointly with our suppliers					
5	We actively involve our key suppliers in new product development processes					

FIGURE 4.2: Question for measuring the construct - early supplier involvement

For evaluating the relative importance of linkages in influencing NPD-SCM alignment, respondents were asked to rate on a nine point scale, the influence of each linkage in improving NPD-SCM alignment of their firm (Figure 4.3). A nine point scale was used in place of a five point scale because data analysis using analytic network process (ANP) required a nine point scale. Details about the nine point scale have been discussed in the next chapter on data analysis. Similarly, the relative influence of various factors on competitive advantage was also measured on a nine point scale.

Please indicate the influence of the following practices in improving the alignment / coordination between NPD and SCM activities of your firm. Please rate the influence on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high level of influence.

		1	2	3	4	5	6	7	8	9
1	Early supplier involvement									
2	Voice of customer									
3	Modularity									
4	Postponement									
5	Supply chain responsiveness									

FIGURE 4.3: Question for measuring influence of linkages on NPD-SCM alignment

To capture the effect of interdependence amongst linkages, a set of queries were framed. For each linkage influencing NPD-SCM alignment, respondents were asked to indicate the influence of remaining linkages on it. For example, respondents were asked to indicate the degree to which early supplier involvement is affected by each of the remaining linkages, while influencing NPD-SCM alignment (Figure 4.4). Similar queries were framed for each of the remaining linkages influencing NPD-SCM alignment. The information from these queries was required to form pair-wise comparison matrices for ANP. The inter-dependence among various factors affecting competitive advantage was also captured using similar set of queries. For example, Figure 4.5 captures the interdependence of remaining factors on cost, while influencing competitive advantage. Similar queries were framed all other factors that affected competitive advantage.

When influencing NPD-SCM alignment of your firm, please indicate the degree to which **early supplier involvement** is affected by each of the following. Please rate the influence on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high level of influence.

		1	2	3	4	5	6	7	8	9
1	Voice of customer									
2	Modularity									
3	Postponement									
4	Supply chain responsiveness									

FIGURE 4.4: Question for capturing influence of remaining linkages on ESI

When influencing competitive advantage of your firm, please indicate the degree to which **cost** is affected by each of the following. Please rate the influence on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high level of influence.

		1	2	3	4	5	6	7	8	9
1	Quality									
2	Delivery									
3	Flexibility									
4	Innovation									

FIGURE 4.5: Question for capturing influence of remaining factors on cost

Last part of the questionnaire sought demographic information from the respondents such as job function, position, work experience, firms' approximate annual sales, workforce, position in Indian automotive supply chain, etc. The final questionnaire is attached as appendix B.

4.3 Sampling Plan

Empirical studies are generally conducted on a representative sample drawn from a population of interest, and conclusions drawn from the sample can be generalized for the entire population.

Therefore, after finalization of the instrument, a large-scale survey was conducted in order to obtain a sample for carrying out data analysis according to the research objectives. As this study focuses on aligning NPD and SCM activities for improving competitive advantage, an industry having significant level of NPD as well as SCM activities would best serve as the population of interest. Automobile industry is one such industry in which the need for high product variety and innovation calls for a high degree of NPD activity; while at the same time, a large number of parts, and presence of global supply chains make SCM an important activity. It is therefore logical to hypothesize that in an automobile industry, alignment between NPD and SCM activities is expected to improve competitive advantage. Automotive industry in India, specially the fast growing passenger car segment, is experiencing a high degree of competition in comparison to other industries in the country, due to the presence of global automakers and their supply chains. The high level of competition, along with significant scope of aligning NPD and SCM activities, have been primary reasons for selecting the Indian automotive industry, as the population of interest for this research.

Data collection is an important aspect of an empirical research, and getting reasonable response rate in retrieving data from industry is usually quite difficult, particularly in countries like India where most companies fear that sharing of any information might adversely affect their competitive advantage. Auto industry, as compared to other industries, has a larger number of organizations comprising of automobile manufacturers, their tier-1 and tier-2 suppliers, and dealers / authorized service centres; thereby increasing the probability of getting a larger sample for the study. Also the researcher had good personal relations with many people working at senior positions across different stage of the Indian automotive industry, and these contacts could help in collecting data for the research, thus making it feasible. These factors formed the secondary considerations for carrying out this study on Indian automotive industry.

4.4 Data collection process

The Indian automotive supply chain consists of three stages -- suppliers, manufacturers and dealers cum after sales service centres. Thus data was required from all the three stages. E-mail addresses of all automobile companies in India were searched using internet based search engines, directories of various groups like the auto component manufacturers' association (ACMA), company websites, list of company authorized dealers and after sales service centres, personal contacts, etc. Since the manufacturers were limited in number, it was decided to include multiple professionals working in different job functions from an organization. The exercise resulted in collection of email addresses of 236 professionals working at supplier stage, 150 professionals working at manufacturer stage, and 262 professionals working at dealer / after sales service centres. To avoid any bias in the study, it was decided to give equal weight age to all the three stages by sending the questionnaire to equal number of respondents across all the three stages. Thus 150 professionals from each stage were selected to maintain the balance between all the stages in such a manner that uniform geographical coverage of the entire population of interest was ensured.

The survey was administered using the web-based method. The questionnaire was uploaded on internet using popular internet survey portal "Survey Monkey", which had a feature of automatically collecting the responses. A brief description of the research objectives was sent via e-mail to a total of 450 professionals along with a request to fill the questionnaire online. A web link (http://www.surveymonkey.com/s/ResearchOnIndianAutomotiveSupplyChain) was provided in the email, and respondents were requested to click the web link for filling the questionnaire. Two follow-up mails were also sent. Out of the 79 responses received, 28 were incomplete having some or the other item(s) unanswered, and therefore these were discarded. Only 51 responses were complete and usable, giving an overall response rate of 11.33%. The details of responses have been summarized in Table 4.4.

TABLE 4.4: Summary of responses

Stage in supply chain	Questionnaire sent	Responses received	Response rate (%)
Suppliers	150	21	14.00
Manufacturers	150	12	8.00
Dealers and after sales service providers	150	18	12.00
Total	450	51	11.33

It may be noted that the response rates were comparatively higher in case of suppliers and dealers, which were usually smaller in size in comparison to big automobile manufacturers; and the professionals working in these organizations and were relatively easily accessible. Also in few cases, through personal relations, a senior executive working in a manufacturing company was approached to forward the researcher's request to his company's suppliers and dealers. In such cases, the response rate was usually high.

4.5 Profile of respondents and surveyed organizations

Responses were received from a variety of professionals working at various job positions, performing different job functions, and having varied work experience. A profile of respondents was developed in order to ensure that the responses covered the Indian automotive supply chain properly and thus can be treated as representative of the entire industry. The profile of respondents has been summarized in Table 4.5 below.

TABLE 4.5: Profile of respondents

S.No.	Characteristics	Supplier (%)	Manufacturer (%)	Dealer (%)
1	**Job position**			
	Top management	9.5	0	16.7
	Senior management	28.6	25.0	27.8
	Middle management	47.6	41.7	44.4
	Engineer / executive	14.3	33.3	11.1
2	**Total work experience**			
	Up to 5years	4.7	8.3	0
	5-10 years	14.3	16.7	11.1
	10-15 years	42.9	33.3	38.9
	15-20 years	23.8	25.0	27.8
	More than 20 years	14.3	16.7	22.2
3	**Job function**			
	Production / operations	23.8	25.0	33.3
	Engineering / product development	23.8	33.3	11.1
	Logistics	33.3	33.3	27.8
	Marketing / sales / customer relations	9.5	8.3	11.1
	Others	9.5	0	16.7

The organizations to which the respondents belonged varied in terms of the size of the work force, annual turnover, and position in the supply chain. A profile of the surveyed organizations was developed to ensure proper representation of the Indian automotive supply chain.

The profile of the surveyed organizations has been summarized in Table 4.6 below.

TABLE 4.6: Profile of surveyed organizations

S. No.	Characteristic	Supplier (%)	Manufacturer (%)	Dealer (%)
1.	**Work force**			
	1-50	4.8	0	72.2
	51-100	19.0	0	27.8
	101-250	38.1	0	0
	251-500	28.6	0	0
	Above 500	9.5	100	0
2	**Approximate annual sales (million USD)**			
	Less than 10	9.5	0	66.7
	10-25	47.6	0	33.3
	25-50	38.1	0	0
	50-100	4.8	0	0
	Above 100	0	100	0
3	**Position in supply chain**			
	Raw material Supplier	9.5	0	0
	Component Supplier	90.5	0	0
	Manufacturer	0	100	0
	Sub-Assembler	0	0	0
	Assembler	0	0	0
	Distributor	0	0	11.1
	Wholesaler	0	0	0
	Retailer	0	0	88.9
	Other	0	0	0

The profiles of respondents and their organizations indicate that the responses cover all the stages of the Indian automotive supply chain properly. Most of the respondents belong to the middle and senior management having ten to twenty years of work experience in job functions such as product development, engineering, logistics, and operations. Thus they are expected to have rich knowledge about NPD and SCM activities in Indian automotive industry and their opinion can be regarded as relevant to the research objectives. Therefore, the sample consisting of the responses of the online survey can be treated as representative of the population comprising the Indian automotive industry.

Responses have been analyzed as per the research objectives using analytic network process, details of which have been presented in the next chapter.

CHAPTER 5

DATA ANALYSIS AND FINDINGS

5.1 Introduction

The preceding chapters discuss how various linkages between new product development and supply chain management activities were short-listed according to their relevance to the Indian automobile industry, and data was collected through an online questionnaire survey to evaluate their impact on NPD-SCM alignment. This chapter addresses the research objectives of prioritizing key linkages according to their impact on NPD-SCM alignment, as well as evaluating the relative importance of NPD-SCM alignment in improving competitive advantage in Indian automotive industry. For the purpose, each variable affecting a criterion is compared one by one with each of the remaining variables on a ratio scale to evaluate which of the two has a greater influence. Such pair-wise comparisons lead towards establishing relative importance among all the variables that influence a particular criterion. In other words, these pair-wise comparisons help in determining the weight age or priority vectors of all the variables. These comparisons are tabulated in form of pair-wise comparison matrices and are analyzed using analytic network process (ANP), in which all the variables influencing a criterion and the interactions amongst them are entered in form of a loose network structure. ANP is a multi-criterion decision making technique that can easily aggregate and model dispersed opinion of respondents, and establish some relationship among the included variables. The variables are generally qualitative in nature and are arranged in a non-hierarchical structure. ANP generally allows a reliable and appropriate analysis of experts' opinion and derives judgment from such a relationship network (Navarro et. al., 2009).

The integrated framework presented in the previous chapter in Figure 4.2 also serves as a loose network for ANP. The thick lines having unidirectional arrowheads depict the influence of all the key linkages on NPD-SCM, and that of various factors on competitive advantage. At the same time, these linkages and factors influence each other, and these inter-actions or inter-dependence are shown by thin lines having arrow-heads in both directions. Both these influences have been captured through the questionnaire as discussed in the last chapter, and the responses have been used to form pair-wise comparison matrices. In this study, the software MATLAB 17b has been used as a programming aid to facilitate implementation of ANP framework.

The various steps involved in data analysis and the findings stemming out of it are described in the succeeding sections.

5.2 Measuring current levels of all variables

Before prioritizing the influence of key linkages on NPD-SCM alignment, first it was felt necessary to find out whether the five key linkages were visible in the Indian automotive industry, and to what extent. For measuring the current levels of all variables, in the questionnaire, a set of five / six items were framed for each of the five key linkages, NPD-SCM alignment, and competitive advantage; and respondents were asked to indicate on a five point Likert scale, the extent to which a particular phenomenon was practiced in their organization. For each response, arithmetic mean of all the items of a variable indicated the extent to which that variable was practiced in the respondent's organization. Similarly, arithmetic mean score of a particular variable across all the responses indicated the degree to which the variable was found to be practiced across the entire Indian automotive industry, as perceived by all the respondents. The results indicated that linkages such as early supplier involvement, voice of customer, modularity, and supply chain responsiveness were visible to a considerable extent, while postponement was being practiced to a small extent only. NPD-SCM alignment and competitive advantage were also observed in the Indian automotive industry to a considerable extent. The values of arithmetic means are summarized in Table 5.1. It can been observed from the table that all the research subjects except postponement are found to be practiced in Indian automotive industry to a considerable extent, which indicates that the respondents have a clear understanding of these subjects.

TABLE 5.1: Presence of research subjects in Indian automotive industry

Variable	Average rating (out of 5)	Degree to which variable is practiced
Early supplier involvement	3.96	To a considerable extent
Voice of customer	4.08	To a considerable extent
Modularity	3.92	To a considerable extent
Postponement	1.84	To a small extent
Supply chain responsiveness	3.90	To a considerable extent
NPD-SCM alignment	4.06	To a considerable extent
Competitive advantage	4.20	To a considerable extent

5.3 Pair-wise comparisons

The impact of various variables along with inter-dependence among them can be captured by ANP through a series of pair-wise comparisons between all the variables that influence a criterion. Pair-wise comparisons were made for all the key linkages that influence NPD-SCM alignment. First, the relative impact of various linkages on NPD-SCM alignment was captured through the questionnaire described in the last chapter. Since ANP uses Saaty's scale, a 9-point scale was used in place of the 5-point Likert scale. A series of pair-wise comparisons were then made to establish the relative importance of these linkages in influencing NPD-SCM alignment. For example, while influencing NPD-SCM alignment, if the influence of the linkage early supplier involvement (ESI) was rated 8 and that of modularity was rated 5, then the pair-wise comparison ESI / modularity would have a value 8 / 5. Similarly, pair-wise comparisons were made for capturing the effect of inter-dependence amongst linkages, i.e. when one linkage was influenced by the remaining linkages. For example, while capturing the influence of remaining linkages on early supplier involvement (ESI), if the influence of VOC on ESI was rated 7 and influence of SCR on ESI was rated 5, then their pair-wise comparison would have the value 7 / 5.

By using the same methodology, pair-wise comparisons were also made to capture the relative impact of various factors influencing competitive advantage, along with the effect of inter-dependence among them. While making pair-wise comparisons, mean scores of variables across all the responses of the questionnaire survey were used as representative of the entire Indian automotive industry.

5.3.1 Development of conversion scale

Analytic network process uses a nine point ratio scale known as Saaty's scale for making pair-wise comparisons. It assigns numerical values to a discrete set of linguistic preferences in proportion to their relative importance. Odd numbers in ascending order on the scale indicate increasing degree of dominance of one variable on the other, while even numbers represent intermediate values. It is generally used for comparing the relative influence of two variables on a criterion. Saaty's scale is shown in Table 5.2 below.

TABLE 5.2: Saaty's scale for pair-wise comparison

Comparison	Verbal scale
1	Equal importance of both variables
3	Moderate importance of one variable over another
5	Strong importance of one variable over another
7	Very strong importance of one variable over another
9	Extreme importance of one variable over another
2,4,6,8	Intermediate values

However, the nine point scale used in the questionnaire was different from Saaty's scale. The scale used in the questionnaire sought only the degree of influence of each variable on the criterion without any comparison between two variables. Saaty's scale was not used in the questionnaire as it would have necessitated a separate set of questions for each pair of variables, thereby making the questionnaire quite lengthy. For instance, the relative influence of all the five key linkages on NPD-SCM alignment was captured using a single set of items (Table 4.5); had Saaty's scale been used, this would have necessitated pair-wise comparison of all possible combinations of two out of five linkages at a time, thereby increasing the number of sets (questions) to C(5,2) = 10. For the entire exercise of comparing the influence of all the five key linkages on NPD-SCM alignment, and that of all six factors on competitive advantage along with inter-dependence, the use of the nine point ratio scale instead of Saaty's scale resulted in an overall reduction in number of questions (set of items) from 115 to 13 (88.7% reduction). However, before using ANP, a conversion scale was developed to convert the responses collected on the nine point ratio scale used in the questionnaire to Saaty's scale by following the steps described in Table 5.3.

TABLE 5.3: Steps for developing conversion scale

1. Calculating all possible ratios

9/1=**9**, 9/2=**4.5**, 9/3=**3**, 9/4=**2.25**, 9/5=**1.8**, 9/6=**1.5**, 9/7=**1.3**, 9/8=**1.125**, 9/9=**1**

8/1=**8**, 8/2=**4,** 8/3=**2.67**, 8/4=**2**, 8/5=**1.6**, 8/6=**1.33**, 8/7=**1.14**, 8/8=**1**

7/1=**7**, 7/2=**3.5**, 7/3=**2.33**, 7/4=**1.75**, 7/5=**1.4**, 7/6=**1.167**, 7/7=**1**

6/1=**6**, 6/2=**3**, 6/3=**2**, 6/4=**1.5**, 6/5=**1.2**, 6/6=**1**

5/1=**5**, 5/2=**2.5**, 5/3=**1.67**, 5/4=**1.25**, 5/5=**1**

4/1=**4**, 4/2=**2**, 4/3=**1.33**, 4/4=**1**

3/1=**3**, 3/2=**1.5**, 3/3=**1**

2/1=**2**, 2/2=**1**

2. Rearranging different ratios in ascending order

1, 1.125, 1.14, 1.167, 1.2, 1.125, 1.3, 1.33, 1.4, 1.5, 1.6, 1.67, 1.75, 1.8, 2, 2.25, 2.33, 2.5, 2.67, 3, 3.5, 4, 4.5, 5, 6,7,8,9 (Total 28 different numbers)

3. Mapping 28 numbers on Saaty's 1-9 scale

i) Ends

	Value of ratio	Value on Saaty's scale
Minimum	1	1
Maximum	9	9

ii) Ratios remaining = 28 – 2 = 26

Values remaining on Saaty's scale = 9 – 2 = 7

Therefore, no. of ratios for each value on Saaty's scale = 26 / 7 = 3.714

Possible combination (by trial and error)

S. No.	Value on Saaty's scale	Number of ratios
1	1	1
2	2	3
3	3	4
4	4	4
5	5	4
6	6	4
7	7	4
8	8	3
9	9	1
TOTAL	**9**	**28**

4. Assigning ratios for each value on Saaty's scale according to the above criterion

The resulting conversion scale for converting the 9-point ratio scale used in the questionnaire to Saaty's scale is shown in Table 5.4.

TABLE 5.4: Conversion scale

S.No.	Ratio	Value	Limiting value	Saaty's scale	Verbal scale
1	1/1, 2/2, 3/3, 4/4, 5/5, 6/6, 7/7, 8/8, 9/9	1	1	1	Equal importance of both elements
2	9/8	1.125	1.1835	2	Intermediate value
3	8/7	1.140			
4	7/6	1.167			
5	6/5	1.200	1.365	3	Moderate importance of one element over another
6	5/4	1.250			
7	9/7	1.300			
8	4/3, 8/6	1.330			
9	7/5	1.400	1.710	4	Intermediate value
10	3/2, 6/4, 9/6	1.500			
11	8/5	1.600			
12	5/3	1.670			
13	7/4	1.750	2.290	5	Strong importance of one element over another
14	9/5	1.800			
15	2/1, 4/2, 6/3, 8/4	2.000			
16	9/4	2.250			
17	7/3	2.330	3.250	6	Intermediate value
18	5/2	2.500			
19	8/3	2.670			
20	3/1, 6/2, 9/3	3.000			
21	7/2	3.500	5.500	7	Very strong importance of one element over another
22	4/1, 8/2	4.000			
23	9/2	4.500			
24	5/1	5.000			
25	6/1	6.000	8.500	8	Intermediate value
26	7/1	7.000			
27	8/1	8.000			
28	9/1	9.000	9	9	Extreme importance of one element over another

5.3.2 Formation of pair-wise comparison matrices

The pair-wise comparisons between all the variables made on a ratio scale of 1–9 were converted to Saaty's scale through the conversion scale shown in Table 5.4, and were entered in a matrix; in the cell formed by intersection of these variables in form of row and column. For example, the mean influence of VOC on ESI was 7.25, and mean influence of modularity on ESI was 6.75. The ratio 7.25 / 6.75 had a value of 2 when converted to the Saaty's scale. Therefore, in the pair-wise comparison matrix for ESI, the cell with row element VOC and column element modularity would have the value 2. Correspondingly, the cell with modularity as row and VOC as column would have an inverse value, i.e. 1 / 2. The above exercise ensured that interpretation of numerical values is according to the Saaty's scale, as required by ANP. For example, a value of 1 in any cell indicates equal importance of two variables, whereas a value of 9 indicates overwhelming dominance of one variable (row component) over the comparison variable (column component). If a variable has weaker impact than its comparison element, the range of values would be from 1 to 1 / 9, where 1 indicates indifference and 1 / 9 represents an overwhelming dominance by a column element over the row element. Table 5.5 shows the pair-wise comparison matrix for one of the linkages.

TABLE 5.5: Pair-wise comparison matrix for ESI

Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
Voice of customer	1	2	4	1/2
Modularity	1/2	1	4	1/2
Postponement	1/4	1/4	1	1/5
Supply chain responsiveness	2	2	5	1

Similarly, pair-wise matrices were formulated for all the remaining linkages, NPD-SCM alignment, competitive advantage and all the factors influencing it.

5.3.3 Computing eigenvectors (eVectors)

Once a pair-wise comparison matrix has been formulated, its eigenvectors need to be computed. Eigenvectors represent the relative weights of the variables that influence a criterion. In this research, eigenvectors have been computed by using a simple algorithm (Jharkharia and Shankar, 2007) mentioned below:

i) Raise the pair-wise comparison matrix to powers that are successively squared each time, till there is no significant change between all the elements in two successive steps.

ii) Calculate the sum of each row in a separate column.

iii) Normalize the above column to get the e-vectors corresponding to each row element.

A computer program was developed in MATLAB R2007b environment using the above algorithm to compute eigenvectors for each pair-wise comparison matrix. The complete pair-wise comparison matrices including eigenvectors for NPD-SCM alignment and all the key linkages influencing it are shown in Table 5.6. Table 5.7 shows the pair-wise comparison matrices for competitive advantage and the factors influencing it.

TABLE 5.6: Pair-wise comparison matrices for NPD-SCM alignment and linkages

(a) NPD- SCM alignment

NPD- SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVectors
Early supplier involvement	1	1/2	1/2	5	2	0.2206
Voice of customer	2	1	2	5	2	0.2941
Modularity	2	1/2	1	5	2	0.2574
Postponement	1/5	1/5	1/5	1	1/5	0.0441
Supply chain responsiveness	1/2	1/2	1/2	5	1	0.1838

(b) Early supplier involvement

Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Voice of customer	1	2	4	1/2	0.2976
Modularity	1/2	1	4	1/2	0.2381
Postponement	1/4	1/4	1	1/5	0.0675
Supply chain responsiveness	2	2	5	1	0.3968

(c) Voice of customer

Voice of customer	Early supplier involvement	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	2	3	1/2	0.3145
Modularity	1/2	1	2	1/2	0.1935
Postponement	1/3	1/2	1	1/3	0.1048
Supply chain responsiveness	2	2	3	1	0.3871

(d) Modularity

Modularity	Early supplier involvement	Voice of customer	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	5	1/2	0.2820
Voice of customer	1	1	5	1/2	0.2820
Postponement	1/5	1/5	1	1/5	0.0602
Supply chain responsiveness	2	2	5	1	0.3759

(e) Postponement

Postponement	Early supplier involvement	Voice of customer	Modularity	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1/2	1/2	0.1667
Voice of customer	1	1	1/2	1/2	0.1667
Modularity	2	2	1	1	0.3333
Supply chain responsiveness	2	2	1	1	0.3333

(f) Supply chain responsiveness

Supply chain responsiveness	Early supplier involvement	Voice of customer	Modularity	Postponement	eVector
Early supplier involvement	1	1/2	1/2	4	0.2381
Voice of customer	2	1	2	5	0.3968
Modularity	2	1/2	1	4	0.2976
Postponement	1/4	1/5	1/4	1	0.0675

TABLE 5.7: Pair-wise comparison matrices for competitive advantage

(a) Competitive advantage

Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	2	2	2	2	3	0.2738
Quality	1/2	1	2	2	2	2	0.2167
Delivery	1/2	½	1	2	1	2	0.1597
Flexibility	1/2	½	1/2	1	2	2	0.1483
Innovation	1/2	½	1	1/2	1	2	0.1255
NPD-SCM alignment	1/3	½	1/2	1/2	1/2	1	0.0760

(b) Cost

Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Quality	1	2	1	1/2	1/2	0.1648
Delivery	½	1	1/2	1/3	1/2	0.0934
Flexibility	1	2	1	1/2	1/2	0.1648
Innovation	2	3	2	1	2	0.3297
NPD-SCM alignment	2	2	2	1/2	1	0.2473

(c) Quality

Quality	Cost	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	2	3	2	2	0.3158
Delivery	½	1	2	2	1/2	0.1895
Flexibility	1/3	1/2	1	1/2	1/3	0.0842
Innovation	½	1/2	2	1	1/2	0.1421
NPD-SCM alignment	½	2	3	2	1	0.2684

(d) **Delivery**

Delivery	Cost	Quality	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	3	1/2	1/2	1	0.1778
Quality	1/3	1	1/4	1/2	1/3	0.0716
Flexibility	2	4	1	3	2	0.3556
Innovation	2	2	1/3	1	1/2	0.1728
NPD-SCM alignment	1	3	1/2	2	1	0.2222

(e) **Flexibility**

Flexibility	Cost	Quality	Delivery	Innovation	NPD-SCM alignment	eVector
Cost	1	1	1/2	1/2	1/3	0.1070
Quality	1	1	1/2	1/2	1/3	0.1070
Delivery	2	2	1	2	1/2	0.2406
Innovation	2	2	1/2	1	1/2	0.1925
NPD-SCM alignment	3	3	2	2	1	0.3529

(f) **Innovation**

Innovation	Cost	Quality	Delivery	Flexibility	NPD-SCM alignment	eVector
Cost	1	2	1	3	2	0.2813
Quality	½	1	1/2	3	2	0.2188
Delivery	1	2	1	3	2	0.2813
Flexibility	1/3	1/3	1/3	1	1/2	0.0781
NPD-SCM alignment	½	1/2	1/2	2	1	0.1406

(g) **NPD-SCM alignment**

NPD-SCM alignment	Cost	Quality	Delivery	Flexibility	Innovation	eVector
Cost	1	2	1/2	1/2	2	0.2034
Quality	½	1	1/2	1/2	1	0.1186
Delivery	2	2	1	2	2	0.3051
Flexibility	2	2	1/2	1	2	0.2542
Innovation	½	1	1/2	1/2	1	0.1186

5.4 Formation of un-weighted super-matrix

The eigenvectors from each pair-wise comparison matrix of Table 5.6 were entered as a column in another matrix called the un-weighted super-matrix for NPD-SCM alignment; under the column element (linkage) for which they were eigenvectors corresponding to the row elements. For example, the eigenvectors from pair-wise comparison matrix for ESI (Table 5.6 b) have been entered as a column in the un-weighted super-matrix for NPD-SCM alignment (Table 5.8) under the column element ESI. Notice that each eigenvector has been placed against the same row element in un-weighted super-matrix, for which it appeared in the pair-wise comparison matrix. The remaining cells in the column have been filled with zeros, since their row elements do not influence that column element. Similarly, eigenvectors from all pair-wise comparison matrices were entered to complete the un-weighted super-matrix. Table 5.8 shows the complete un-weighted super-matrix for NPD-SCM alignment.

TABLE 5.8: Un-weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2206	0	0.3145	0.2820	0.1667	0.2381
Voice of customer	0.2941	0.2976	0	0.2820	0.1667	0.3968
Modularity	0.2574	0.2381	0.1935	0	0.3333	0.2976
Postponement	0.0441	0.0675	0.1048	0.0602	0	0.0675
Supply chain responsiveness	0.1838	0.3968	0.3871	0.3759	0.3333	0

Eigenvectors drawn from the pair-wise comparison matrix of a linkage represent weight age of the influence of remaining linkages on it. Therefore, each column of the un-weighted super-matrix of NPD-SCM alignment represents the influence of all the row elements (linkages) on that column element (linkage), when the column element (linkage) is influencing the criterion (NPD-SCM alignment). In this manner, the un-weighted super-matrix for NPD-SCM alignment captures the indirect influence of all the linkages on NPD-SCM alignment due to inter-dependence among them. The direct influence of all the key linkages has already been captured in the second column under the heading NPD-SCM alignment that exhibits the eigenvectors of pair-wise comparison matrix of NPD-SCM alignment (Table 5.6 a), which represent the relative influence of key linkages on NPD-SCM alignment directly.

By following a similar procedure, an un-weighted super-matrix for competitive advantage has also been formulated, and is shown in Table 5.9.

TABLE 5.9: Un-weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.2738	0	0.3158	0.1778	0.1070	0.2813	0.2034
Quality	0.2167	0.1648	0	0.0716	0.1070	0.2188	0.1186
Delivery	0.1597	0.0934	0.1895	0	0.2406	0.2813	0.3051
Flexibility	0.1483	0.1648	0.0842	0.3556	0	0.0781	0.2542
Innovation	0.1255	0.3297	0.1421	0.1728	0.1925	0	0.1186
NPD-SCM alignment	0.0760	0.2473	0.2684	0.2222	0.3529	0.1406	0

5.5 Formation of weighted super-matrix

Since each column of the un-weighted super-matrix represents weight age of the influence of row elements on the column element, ideally the sum of each column must add up to unity. However, as the value of eigenvectors have been taken only up to 4 places after decimal point, there is a possibility that sum of any particular column may deviate from unity by a very narrow margin. However, the matrix operation for the next step in ANP requires that the sum of each column must strictly be equal to 1. Therefore, each column of the matrix must be normalized such that its sum equals exactly unity. The resulting matrix is known as weighted super-matrix in which the sum of each column is exactly equal to unity. The un-weighted super-matrices for both NPD-SCM alignment and competitive advantage have been converted into weighted super-matrices, and are shown in Table 5.10 and Table 5.11.

TABLE 5.10: Weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2206	0	0.3145	0.2820	0.1667	0.2381
Voice of customer	0.2941	0.2976	0	0.2820	0.1667	0.3968
Modularity	0.2574	0.2381	0.1935	0	0.3333	0.2976
Postponement	0.0441	0.0675	0.1049	0.0601	0	0.0675
Supply chain responsiveness	0.1838	0.3968	0.3871	0.3759	0.3333	0

TABLE 5.11: Weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.2738	0	0.3158	0.1778	0.1070	0.2813	0.2034
Quality	0.2167	0.1648	0	0.0716	0.1070	0.2187	0.1187
Delivery	0.1597	0.0934	0.1895	0	0.2406	0.2813	0.3051
Flexibility	0.1483	0.1648	0.0842	0.3556	0	0.0781	0.2542
Innovation	0.1255	0.3297	0.1421	0.1728	0.1925	0	0.1186
NPD-SCM alignment	0.0760	0.2473	0.2684	0.2222	0.3529	0.1406	0

5.6 Formation of limit super-matrix

The last step of ANP requires formation of limit super-matrix, which gives priority vectors of all the elements influencing a criterion. The weighted super-matrix for NPD-SCM alignment was converged by multiplying it a number of times by itself until it became stable, i.e. entities in all rows stopped changing their values. A computer program was developed using software MATLAB 17b for converging the matrix. The converged matrix so obtained is called limit super-matrix for NPD-SCM alignment and is shown in Table 5.12. All columns of the limit super-matrix are identical and represent priority vectors or relative weights of all row elements (linkages) in influencing the criterion (NPD-SCM alignment). Limit super-matrix for competitive advantage was also computed by the same method, and is presented in Table 5.13. The priority vectors indicating weight age of various factors influencing competitive advantage can be read from any column of the limit super-matrix.

TABLE 5.12: Limit super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2103	0.2103	0.2103	0.2103	0.2103	0.2103
Voice of customer	0.2409	0.2409	0.2409	0.2409	0.2409	0.2409
Modularity	0.2023	0.2023	0.2023	0.2023	0.2023	0.2023
Postponement	0.0703	0.0703	0.0703	0.0703	0.0703	0.0703
Supply chain responsiveness	0.2762	0.2762	0.2762	0.2762	0.2762	0.2762

TABLE 5.13: Limit super-matrix for competitiveness advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1732	0.1732	0.1732	0.1732	0.1732	0.1732	0.1732
Quality	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182
Delivery	0.1840	0.1840	0.1840	0.1840	0.1840	0.1840	0.1840
Flexibility	0.1666	0.1666	0.1666	0.1666	0.1666	0.1666	0.1666
Innovation	0.1611	0.1611	0.1611	0.1611	0.1611	0.1611	0.1611
NPD-SCM alignment	0.1969	0.1969	0.1969	0.1969	0.1969	0.1969	0.1969

5.7 Findings

The results of data analysis give the priority vectors for all the five key linkages influencing NPD-SCM alignment, as well as the priority vectors for various factors affecting competitive advantage. The priority vectors represent the relative contribution of various column elements in influencing the criterion. In order to interpret the influence of variables, the priority vectors have been graded in the following manner. Since sum of all priority vectors is invariably equal to unity, one divided by the number of priority vectors would give the average score if all the variables have equal influence. This score has been graded as ‘moderate’. The scores of priority vectors have been distributed in a manner such that scores above ‘moderate’ have been distributed uniformly in two grades ‘high’ and ‘very high’, and scores below ‘moderate’ have been distributed uniformly in the grades ‘low’ and ‘very low’. For example, priority vectors drawn from the limit super-matrix for NPD-SCM alignment indicate that influence of linkages such as supply chain responsiveness (0.2762) and voice of customer (0.2409) is very high; that of early supplier involvement (0.2103) and modularity (0.2023) is high; while the priority vector of postponement is very low (0.0703), which indicates that NPD-SCM alignment is not much affected by postponement. Table 5.14 summarizes findings of the survey in form of degree of importance of all the key linkages in influencing NPD-SCM alignment. Since the data given as input for calculating the limit super-matrix contained mean values across all responses, the resulting priority vectors are representative of the entire Indian automotive industry. The possible reasons for variation in the degree of influence of the key linkages shall be discussed later in greater detail in the coming chapters.

TABLE 5.14: Findings of survey – NPD-SCM alignment

Linkages	Priority vector	Degree of importance
Early supplier involvement	0.2103	High
Voice of customer	0.2409	Very high
Modularity	0.2023	High
Postponement	0.0703	Very low
Supply chain responsiveness	0.2762	Very high

Similarly Table 5.15 exhibits findings of the survey related to competitive advantage in Indian automotive industry. It indicates that competitive advantage is influenced most by NPD-SCM alignment (0.1969), delivery (0.1840), and cost (0.1732). Flexibility (0.1666) and innovation (0.1611) also have a high influence, while the impact of quality came out to be low (0.1182). The possible reasons for disparity in the degree of influence of various factors on competitive advantage shall be discussed in the later chapters.

TABLE 5.15: Findings of survey – competitive advantage

Factors	Priority vector	Degree of importance
Cost	0.1732	High
Quality	0.1182	Low
Delivery	0.1840	High
Flexibility	0.1666	High
Innovation	0.1611	High
NPD-SCM alignment	0.1969	High

The priority vectors calculated by the above process indicate the importance of various linkages in influencing NPD-SCM alignment, and its resulting impact on competitive advantage in comparison to other factors. However, before accepting these results, it would be proper to validate these findings to ascertain their correctness and applicability across the entire Indian automotive supply chain comprising of different stages such as supplier, manufacturer, and customer (dealer). Next chapter attempts to investigate these issues through some case studies performed at individual organizations across different stages of the Indian automotive supply chain, and explores reasons for variation among the findings.

CHAPTER 6

CASE STUDIES

6.1 Introduction

Case studies are generally used to validate findings of a large scale survey, since they provide deeper insights into a phenomenon. Case research examines the actual phenomenon in a real environment using exploratory investigations to develop better understanding of the process, and the outcome can be generalized at a larger scale for similar populations under similar conditions. Case studies are aimed at searching for answers to questions such as 'how' and 'why' of any phenomenon, and thus often provide qualitative analysis of the quantitative outcome of survey based researches. Therefore, case study method has been used in this research to validate findings of the large-scale survey. Three longitudinal case studies have been designed, one each at supplier, manufacturer, and customer (dealer) stage of the Indian automotive supply chain. Inferences drawn from these case studies have been used to substantiate outcome of the large-scale survey

6.2 Selection of responding organizations

The Indian automotive supply chain comprises of mainly three stages – suppliers, manufacturers, and dealers cum after sales service centers. Therefore, case studies need to be performed at each of these stages in order to validate findings of the survey for the entire Indian automotive industry. As in case of any automotive supply chain, a general observation about Indian automotive supply chain is that the number of automobile manufacturing companies is much smaller in comparison to the number of component suppliers, and dealers. Most auto makers have their own dedicated network of a large number of authorized dealers for sales and after sales service. In contrast to dealership network, the suppliers are not dedicated to any particular manufacturer, i.e. one supplier may provide components to many auto makers, and one auto manufacturer procures similar parts from many suppliers. For example, companies like Apollo, Bridgestone, and MRF supply tyres with same specifications to major auto makers such as Maruti, Hyundai, Honda, Tata, etc. At the same time, these auto makers also use in their cars, tyres of different make having same specifications. Thus, in order to maintain balance, it was decided to take up case studies in equal number of organizations in all three supply chain stages.

Since manufacturing organizations were fewer in number, and not easily accessible in comparison to suppliers and dealers, it was decided to first approach the manufacturers to seek their permission for conducting case study; followed by persuading suppliers and dealers equal in number to the manufacturers giving their consent. Five major automobile manufacturing companies having production facilities located in India were approached. After using personal relations and serious follow up efforts, only one company finally agreed to participate in the validation process. Consequently, permission to conduct case study was taken from one supplier and one dealer, which was relatively an easier task. While selecting the supplier, care was taken to choose a supplier who supplies components to majority of manufacturers including the one selected, thus ensuring that the supplier had a significant presence in the supply chain. The dealer chosen for the case study was an authorized dealer cum after sales service provider of a leading auto manufacturer, selected from amongst the remaining four major manufacturing companies approached earlier, deliberately omitting the manufacturer selected for the case study. The rationale was once again to cover the Indian automotive supply chain as much as possible, and not restrict the study to a particular company. Since confidentiality of information was promised to all the organizations participating in the case study, original names of the firms have not been disclosed in this thesis, and they have been addressed as Supplier, Manufacturer, and Dealer.

6.3 Methodology

The case studies were conducted using a systematic methodology involving data collection through observation in plants, interviews, questionnaire, and archives to collect the qualitative as well as quantitative evidences. Several visits were made to the case companies to observe and understand the practices followed by the case firms. This helped in comprehending the company's viewpoint towards research objectives. Executives having decision-making roles, working at different hierarchy levels with at least five years of experience in the company were chosen from different job functions as respondents. The purpose of the research was clearly explained to the executives as well as to the top management.

The same questionnaire which was used for large-scale survey was adopted with some modifications. These modifications were in form of some open ended questions related to competitive policies, production strategies, design and process thinking capabilities, business environment, company specific strategies, and other key performance indicators of the firm. Open ended questions helped in developing clear understanding of practices being followed in the case company, specially related to the rationale behind the responses for making pair-wise comparison. An overview of questionnaire was first described before asking questions. The responses were documented manually in already prepared manuscripts. Wherever required, queries were discussed until the question was clearly understood by the executives. Open discussions were held with senior management, which helped in exploring various management practices followed by the case companies and their competitors. These were also helpful in gathering information about prominent business strategies related to national and international automotive supply chains.

The responses so obtained were quantitative as well as descriptive in nature. Similar to the methodology used for large-scale survey, the quantitative data was used to form pair-wise comparison matrices, which were solved using ANP, the systematic procedure of which has already been mentioned in section 5.3 and 5.4. The programming was done using MATLAB 17b software suite to compute the limit super matrices.

6.4 Case study 1- Supplier

The first case study has been carried out at the supplier stage of the Indian automotive industry. The name of the firm has not been disclosed to maintain confidentiality. However, a brief description about the company is given below.

6.4.1 Profile of the organization

The case company is an auto component manufacturer of Indian origin, having multiple manufacturing plants located in North India. It started about 40 years back as a proprietary concern and in early 1980s, was converted to a public limited company. It produces more than 800 types of lighting equipment for passenger cars and commercial vehicles. This includes over 500 types of head lamps, 100 varieties of work lamps, and nearly 200 other types of lamps such as indicator lamps, cabin lamps, tail lamps, marker lamps and license lamps. The product portfolio extends to tail and side lamp bulbs, asymmetrical bulbs, multi-surface reflector lamps, dash board and side meter lamps, reversing lamps, rear and number plate lamps, rectangular and squared LED work lamps, and wedge based lamps. Company’s product range finds application in a variety of vehicles such as passenger cars, light commercial vehicles, utility vehicles, buses, trucks, tractors and even in housing. The wide product range is used as a strategy to increase market share and simultaneously improve profit margins as well.

The company is in strategic agreement with several national and multinational auto-assemblers for supply of lighting products. Its major customers in India include Maruti Suzuki, Tata Motors, Hindustan Motors, Escorts, Mahindra and Mahindra, Fiat, Eicher, Force Motors, JCBL group companies, TAFE, Ashok Leyland, Swaraj Mazda, Yamaha, Sonalika International, and Larsen and Toubro. The company is a market leader in domestic market, with a widespread network of dealers and distributors in almost all urban and rural market segments of India. It also exports its products to more than 60 countries, with approximately two-third of its turnover coming from exports to Asia, US, and Europe. A sister concern in Texas, US has been set up for distribution of products in US, Canada and neighboring regions. The company faces major competition from firms such as Lumax Industries Limited, New Light India, Jagan Lamps Limited, Phoenix Lights, Minda Lightings, FIEM Industries Limited, and Satellite Engineering Limited. In March 2013, the company reported annual sales of 1,166 million Indian National Rupees (21.2 million USD) and net worth of 704 million INR (12.8 million USD). Its sales have experienced a tremendous growth of nearly 60 percent over the last 5 years, including nearly 13 percent during last year.

In order to meet increasing industrial pressure of supplying cost effective high quality products along with on-time delivery, the company has developed multiple growth plans for the future. Some of these plans include plant capacity expansion, increased investment in R&D activities, and designing and implementing market specific strategies.

6.4.2 Results

Data was collected from the case company using the methodology described in section 6.3. Data analysis was carried out using analytic network process (ANP) following the steps described in chapter 5. The results of data analysis are presented in Tables 6.1 to 6.8.

TABLE 6.1: Pair-wise comparison matrices for NPD-SCM alignment and linkages

(g) NPD- SCM alignment

NPD- SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1/2	1	4	2	0.2220
Voice of customer	2	1	2	5	3	0.3396
Modularity	1	1/2	1	4	2	0.2220
Postponement	1/4	1/5	1/4	1	1/4	0.0509
Supply chain responsiveness	1/4	1/3	1/2	4	1	0.1654

(h) Early supplier involvement

Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Voice of customer	1	2	4	1	0.3368
Modularity	1/2	1	4	1/2	0.2526
Postponement	1/4	1/4	1	1/4	0.0737
Supply chain responsiveness	1	2	4	1	0.3368

(i) Voice of customer

Voice of customer	Early supplier involvement	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1/2	1	0.2000
Modularity	1	1	1/2	1	0.2000
Postponement	2	2	1	2	0.4000
Supply chain responsiveness	1	1	1/2	1	0.2000

(j) Modularity

Modularity	Early supplier involvement	Voice of customer	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	6	1	0.3158
Voice of customer	1	1	6	1	0.3158
Postponement	1/6	1/6	1	1/6	0.0526
Supply chain responsiveness	1	1	6	1	0.3158

(k) Postponement

Postponement	Early supplier involvement	Voice of customer	Modularity	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1/3	1	0.1667
Voice of customer	1	1	1/3	1	0.1667
Modularity	3	3	1	3	0.5000
Supply chain responsiveness	1	1	1/3	1	0.1667

(l) Supply chain responsiveness

Supply chain responsiveness	Early supplier involvement	Voice of customer	Modularity	Postponement	eVector
Early supplier involvement	1	1/3	1	6	0.2593
Voice of customer	3	1	3	7	0.4356
Modularity	1	1/3	1	6	0.2593
Postponement	1/6	1/7	1/6	1	0.0459

TABLE 6.2: Un-weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2220	0	0.2000	0.3158	0.1667	0.2593
Voice of customer	0.3396	0.3368	0	0.3158	0.1667	0.4356
Modularity	0.2220	0.2526	0.2000	0	0.5000	0.2593
Postponement	0.0509	0.0737	0.4000	0.0526	0	0.0459
Supply chain responsiveness	0.1654	0.3368	0.2000	0.3158	0.1667	0

TABLE 6.3: Weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2220	0	0.2000	0.3158	0.1667	0.2593
Voice of customer	0.3397	0.3368	0	0.3158	0.1667	0.4355
Modularity	0.2220	0.2527	0.2000	0	0.4999	0.2593
Postponement	0.0509	0.0737	0.4000	0.0526	0	0.0459
Supply chain responsiveness	0.1654	0.3368	0.2000	0.3158	0.1667	0

TABLE 6.4: Limit super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.1943	0.1943	0.1943	0.1943	0.1943	0.1943
Voice of customer	0.2467	0.2467	0.2467	0.2467	0.2467	0.2467
Modularity	0.2189	0.2189	0.2189	0.2189	0.2189	0.2189
Postponement	0.1340	0.1340	0.1340	0.1340	0.1340	0.1340
Supply chain responsiveness	0.2062	0.2062	0.2062	0.2062	0.2062	0.2062

TABLE 6.5: Pair-wise comparison matrices for competitive advantage

(a) Competitive advantage

Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	2	2	1	1	1	0.2000
Quality	1/2	1	1	1/2	1/2	1/2	0.1000
Delivery	1/2	1	1	1/2	1/2	1/2	0.1000
Flexibility	1	2	2	1	1	1	0.2000
Innovation	1	2	2	1	1	1	0.2000
NPD-SCM alignment	1	2	2	1	1	1	0.2000

(b) Cost

Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Quality	1	1	1/4	1/5	1/5	0.0589
Delivery	1	1	1/4	1/5	1/5	0.0589
Flexibility	4	4	1	1/8	1/3	0.2150
Innovation	5	5	3	1	1	0.3336
NPD-SCM alignment	5	5	3	1	1	0.3336

(c) Quality

Quality	Cost	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	1/3	6	4	1/4	0.2128
Delivery	3	1	6	5	1/2	0.2848
Flexibility	1/6	1/6	1	1/4	1/7	0.0317
Innovation	1/4	1/5	4	1	1/6	0.1032
NPD-SCM alignment	4	2	7	6	1	0.3675

(d) Delivery

Delivery	Cost	Quality	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	6	1/3	3	1/3	0.2047
Quality	1/6	1	1/7	1/6	1/7	0.0311
Flexibility	3	7	1	4	1	0.3070
Innovation	1/3	6	1/4	1	1/4	0.1503
NPD-SCM alignment	3	7	1	4	1	0.3070

(e) Flexibility

Flexibility	Cost	Quality	Delivery	Innovation	NPD-SCM alignment	eVector
Cost	1	1/3	1/4	1/4	1/4	0.0559
Quality	3	1	1/3	1/2	1/3	0.1387
Delivery	4	3	1	2	1	0.2953
Innovation	4	2	1/2	1	1/2	0.2148
NPD-SCM alignment	4	3	1	2	1	0.2953

(f) Innovation

Innovation	Cost	Quality	Delivery	Flexibility	NPD-SCM alignment	eVector
Cost	1	2	1	8	3	0.2795
Quality	1/2	1	1/2	8	2	0.2236
Delivery	1	2	1	8	3	0.2795
Flexibility	1/8	1/8	1/8	1	1/8	0.0280
NPD-SCM alignment	1/3	½	1/3	8	1	0.1894

(g) NPD-SCM alignment

NPD-SCM alignment	Cost	Quality	Delivery	Flexibility	Innovation	eVector
Cost	1	3	1	1	4	0.2697
Quality	1/3	1	1/3	1/3	3	0.1348
Delivery	1	3	1	1	4	0.2697
Flexibility	1	3	1	1	4	0.2697
Innovation	1/4	½	1/4	1/4	1	0.0562

TABLE 6.6: Un-weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.2000	0	0.2128	0.2047	0.0559	0.2795	0.2697
Quality	0.1000	0.0589	0	0.0311	0.1389	0.2236	0.1348
Delivery	0.1000	0.0589	0.2848	0	0.2953	0.2795	0.2697
Flexibility	0.2000	0.2150	0.0317	0.3070	0	0.0280	0.2697
Innovation	0.2000	0.3336	0.1032	0.1503	0.2148	0	0.0562
NPD-SCM alignment	0.2000	0.3336	0.3675	0.3070	0.2953	0.1894	0

TABLE 6.7: Weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.2000	0	0.2128	0.2047	0.0559	0.2795	0.2697
Quality	0.1000	0.0589	0	0.0311	0.1389	0.2236	0.1347
Delivery	0.1000	0.0589	0.2848	0	0.2952	0.2795	0.2697
Flexibility	0.2000	0.2150	0.0317	0.3070	0	0.0280	0.2697
Innovation	0.2000	0.3336	0.1032	0.1502	0.2148	0	0.0562
NPD-SCM alignment	0.2000	0.3336	0.3675	0.3070	0.2952	0.1894	0

TABLE 6.8: Limit super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1716	0.1716	0.1716	0.1716	0.1716	0.1716	0.1716
Quality	0.1019	0.1019	0.1019	0.1019	0.1019	0.1019	0.1019
Delivery	0.1895	0.1895	0.1895	0.1895	0.1895	0.1895	0.1895
Flexibility	0.1640	0.1640	0.1640	0.1640	0.1640	0.1640	0.1640
Innovation	0.1443	0.1443	0.1443	0.1443	0.1443	0.1443	0.1443
NPD-SCM alignment	0.2286	0.2286	0.2286	0.2286	0.2286	0.2286	0.2286

6.4.3 Findings

Table 6.9 shows the extent to which all the variables were being practiced in the firm. The results of data analysis showing the priority vectors of key linkages influencing NPD-SCM alignment and their significance have been summarized in Table 6.10. Similarly, priority vectors of various factors influencing competitive advantage and their implications have been presented in Table 6.11.

TABLE 6.9: Visibility of variables in case company 1 (supplier)

Variable	Average rating (out of 5)	Degree to which variable is present
Early supplier involvement	3.18	To a moderate extent
Voice of customer	4.64	To a great extent
Modularity	4.19	To a considerable extent
Postponement	2.36	To a small extent
Supply chain responsiveness	4.00	To a considerable extent
NPD-SCM alignment	4.00	To a considerable extent
Competitive advantage	4.09	To a considerable extent

TABLE 6.10: Influence of linkages on NPD-SCM alignment - case study 1 (supplier)

Linkages	Priority vector	Degree of importance
Early supplier involvement	0.1943	Moderate
Voice of customer	0.2467	Very High
Modularity	0.2189	High
Postponement	0.1340	Low
Supply chain responsiveness	0.2062	High

TABLE 6.11: Influence of various factors on competitive advantage - case study 1 (supplier)

Factors	Priority vector	Degree of importance
Cost	0.1716	High
Quality	0.1019	Low
Delivery	0.1895	High
Flexibility	0.1640	High
Innovation	0.1443	Moderate
NPD-SCM alignment	0.2286	Very high

6.5 Case study 2- Manufacturer

The second case study was taken up at the manufacturer stage of the Indian automotive industry. The name of the company has not been disclosed to maintain confidentiality. However, a brief description about the company is given below.

6.5.1 Profile of the organization

The company is among three largest automobile manufacturers in India, contributing to nearly one-third of total industry sales in domestic market. It was founded nearly 30 years back in collaboration with a renowned foreign company. At present, it is manufacturing 10 models of passenger cars, and 5 models of utility vehicles in two state-of-the art manufacturing facilities, both located in North India. One of the facilities has three plants having a production capacity of 300,000 units each, while the other has an installed capacity of 550,000 units in a single plant. The overall capacity at present is to produce over 1,450,000 automobiles in a year. There are plans to increase the capacity further by setting up two more manufacturing facilities in western part of the country. Out of the total installed capacity, the company currently produces more than one million automobile units annually, with 15 different models and over 200 variants. It also exports its vehicles manufactured in India to markets of Europe, Latin America, Africa and Asia, in countries such as Angola, Benin, Djibouti, Ethiopia, Kenya, Morocco, Nepal, Sri Lanka, Uganda, Chile, Guatemala, Costa Rica, and El Salvador.

Service is another major source of revenue generator for the company. Most of the service stations are managed on franchise basis where the company trains the local staff. By the end of financial year 2013, the company had a strong network of 1204 dealers across 874 towns and cities in all the states and Union territories of India; and 2976 service stations in 1395 towns and cities, including 30 express service stations on 30 national highways. It was ranked no. 1 in the JD Power customer satisfaction index for the twelfth consecutive year in 2012.

The company works on the strategy of using light weight compact engines having stronger power, fuel efficiency and performance capabilities. Material cost is the most significant component of the total cost, and accounts for 76.3% of the total cost. The company has state-of-the art manufacturing facilities equipped with sophisticated machine tools including 150 robots, and as a result, labor cost sums up to only 2.5% of the total cost. Administrative and office expensive cover 10.8%, while selling and distributing expenses account for 2.8% of the total cost. The company is facing some challenges in form of decreasing sales of petrol vehicles due to increase in petrol prices, and increased costs of imported parts due to appreciating prices of Yen / Dollar in comparison to the Indian Rupee. Over the last few years, exports to European nations have also decreased sharply due to withdrawal of scrappage incentive schemes. The company has tried to meet these challenges by focusing more on diesel vehicles and promoting exports to non-European countries. The company has also diversified its operations in other business sectors such as insurance, finance, pre-owned cars, genuine accessories and parts, driving school, and end-to-end fleet management (providing lease and fleet management solutions to corporate such as Gas Authority of India Ltd., DuPont, Reckitt Benckiser, Sona steering, etc.).

The company is listed both in Bombay stock exchange (BSE) as well as National stock exchange (NSE) in India. At the end of financial year 2012-13, it had a net worth of 185,789 million INR (3378 million USD) and approximately 9,500 employees. During financial year 2012-13, it managed to sell 1,051,046 units in the domestic market, and exported 120,388 vehicles overseas, recording net sales of 426,125 million INR (7747 million USD), and profit after tax of 23, 921 million INR (435 million USD).

6.5.2 Results

Methodology similar to that used for case study 1 was adopted for data collection and analysis. The results are presented in Tables 6.12 to Table 6.19.

TABLE 6.12: Pair-wise comparison matrices for NPD-SCM alignment and linkages

(a) NPD- SCM alignment

NPD- SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1	8	1	0.2424
Voice of customer	1	1	1	8	1	0.2424
Modularity	1	1	1	8	1	0.2424
Postponement	1/8	1/8	1/8	1	1/8	0.0303
Supply chain responsiveness	1	1	1	8	1	0.2424

(b) Early supplier involvement

Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Voice of customer	1	1	8	1	0.3200
Modularity	1	1	8	1	0.3200
Postponement	1/8	1/8	1	1/8	0.0400
Supply chain responsiveness	1	1	8	1	0.3200

(c) Voice of customer

Voice of customer	Early supplier involvement	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	8	1	0.3200
Modularity	1	1	8	1	0.3200
Postponement	1/8	1/8	1	1/8	0.0400
Supply chain responsiveness	1	1	8	1	0.3200

(d) Modularity

Modularity	Early supplier involvement	Voice of customer	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	8	1	0.3200
Voice of customer	1	1	8	1	0.3200
Postponement	1/8	1/8	1	1/8	0.0400
Supply chain responsiveness	1	1	8	1	0.3200

(e) Postponement

Postponement	Early supplier involvement	Voice of customer	Modularity	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1	1	0.2500
Voice of customer	1	1	1	1	0.2500
Modularity	1	1	1	1	0.2500
Supply chain responsiveness	1	1	1	1	0.2500

(f) Supply chain responsiveness

Supply chain responsiveness	Early supplier involvement	Voice of customer	Modularity	Postponement	eVector
Early supplier involvement	1	1	8	1	0.3200
Voice of customer	1	1	8	1	0.3200
Modularity	1/8	1/8	1	1/8	0.0400
Postponement	1	1	8	1	0.3200

TABLE 6.13: Un-weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2424	0	0.3200	0.3200	0.2500	0.3200
Voice of customer	0.2424	0.3200	0	0.3200	0.2500	0.3200
Modularity	0.2424	0.3200	0.3200	0	0.2500	0.3200
Postponement	0.0303	0.0400	0.0400	0.0400	0	0.0400
Supply chain responsiveness	0.2424	0.3200	0.3200	0.3200	0.2500	0

TABLE 6.14: Weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2424	0	0.3200	0.3200	0.2500	0.3200
Voice of customer	0.2424	0.3200	0	0.3200	0.2500	0.3200
Modularity	0.2424	0.3200	0.3200	0	0.2500	0.3200
Postponement	0.0302	0.0400	0.0400	0.0400	0	0.0400
Supply chain responsiveness	0.2424	0.3200	0.3200	0.3200	0.2500	0

TABLE 6.15: Limit super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2403	0.2403	0.2403	0.2403	0.2403	0.2403
Voice of customer	0.2403	0.2403	0.2403	0.2403	0.2403	0.2403
Modularity	0.2403	0.2403	0.2403	0.2403	0.2403	0.2403
Postponement	0.0385	0.0385	0.0385	0.0385	0.0385	0.0385
Supply chain responsiveness	0.2403	0.2403	0.2403	0.2403	0.2403	0.2403

TABLE 6.16: Pair-wise comparison matrices for competitive advantage

(a) Competitive advantage

Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	1	2	2	1/2	1	0.1522
Quality	1	1	3	3	1/2	1	0.1928
Delivery	1/2	1/3	1	1	1/4	1/3	0.0693
Flexibility	1/2	1/3	1	1	1/5	1/3	0.0683
Innovation	2	2	4	5	1	2	0.3247
NPD-SCM alignment	1	1	3	3	1/2	1	0.1928

(b) Cost

Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Quality	1	3	2	1/2	1	0.2284
Delivery	1/3	1	1/2	1/3	1/3	0.0761
Flexibility	1/2	2	1	1/3	1/2	0.1320
Innovation	2	3	3	1	2	0.3350
NPD-SCM alignment	1	3	2	1/2	1	0.2284

(c) Quality

Quality	Cost	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	2	2	1	1	0.2222
Delivery	1/2	1	1	1/4	1/2	0.1032
Flexibility	1/2	1	1	1/4	1/2	0.1032
Innovation	2	4	4	1	1	0.3492
NPD-SCM alignment	1	2	2	1	1	0.2222

(d) Delivery

Delivery	Cost	Quality	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	1	1	1	1	0.2000
Quality	1	1	1	1	1	0.2000
Flexibility	1	1	1	1	1	0.2000
Innovation	1	1	1	1	1	0.2000
NPD-SCM alignment	1	1	1	1	1	0.2000

(e) Flexibility

Flexibility	Cost	Quality	Delivery	Innovation	NPD-SCM alignment	eVector
Cost	1	1	1	1	1	0.2000
Quality	1	1	1	1	1	0.2000
Delivery	1	1	1	1	1	0.2000
Innovation	1	1	1	1	1	0.2000
NPD-SCM alignment	1	1	1	1	1	0.2000

(f) Innovation

Innovation	Cost	Quality	Delivery	Flexibility	NPD-SCM alignment	eVector
Cost	1	1	1	1	2	0.2222
Quality	1	1	1	1	2	0.2222
Delivery	1	1	1	1	2	0.2222
Flexibility	1/2	½	1/2	1/2	1	0.1111
NPD-SCM alignment	1	1	1	1	2	0.2222

(g) NPD-SCM alignment

NPD-SCM alignment	Cost	Quality	Delivery	Flexibility	Innovation	eVector
Cost	1	1	1	1	1	0.2000
Quality	1	1	1	1	1	0.2000
Delivery	1	1	1	1	1	0.2000
Flexibility	1	1	1	1	1	0.2000
Innovation	1	1	1	1	1	0.2000

TABLE 6.17: Un-weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1522	0	0.2222	0.2000	0.2000	0.2222	0.2000
Quality	0.1928	0.2284	0	0.2000	0.2000	0.2222	0.2000
Delivery	0.0693	0.0761	0.1032	0	0.2000	0.2222	0.2000
Flexibility	0.0683	0.1320	0.1032	0.2000	0	0.1112	0.2000
Innovation	0.3247	0.3350	0.3492	0.2000	0.2000	0	0.2000
NPD-SCM alignment	0.1928	0.2284	0.2222	0.2000	0	0.2222	0

TABLE 6.18: Weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1522	0	0.2222	0.2000	0.2000	0.2222	0.2000
Quality	0.1927	0.2284	0	0.2000	0.2000	0.2222	0.2000
Delivery	0.0693	0.0762	0.1032	0	0.2000	0.2222	0.2000
Flexibility	0.0683	0.1320	0.1032	0.2000	0	0.1112	0.2000
Innovation	0.3247	0.3350	0.3492	0.2000	0.2000	0	0.2000
NPD-SCM alignment	0.1927	0.2284	0.2222	0.2000	0	0.2222	0

TABLE 6.19: Limit super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1737	0.1737	0.1737	0.1737	0.1737	0.1737	0.1737
Quality	0.1746	0.1746	0.1746	0.1746	0.1746	0.1746	0.1746
Delivery	0.1385	0.1385	0.1385	0.1385	0.1385	0.1385	0.1385
Flexibility	0.1273	0.1273	0.1273	0.1273	0.1273	0.1273	0.1273
Innovation	0.2079	0.2079	0.2079	0.2079	0.2079	0.2079	0.2079
NPD-SCM alignment	0.1778	0.1778	0.1778	0.1778	0.1778	0.1778	0.1778

6.5.3 Findings

Table 6.20 shows the visibility of all the variables in form of the extent to which they are present in the firm. The priority vectors of key linkages influencing NPD-SCM alignment computed through ANP and their significance have been summarized in Table 6.21. Similarly, priority vectors of various factors influencing competitive advantage along with their implications have been presented in Table 6.22.

TABLE 6.20: Visibility of variables in case company 2 (manufacturer)

Variable	Average rating (out of 5)	Degree to which variable is present
Early supplier involvement	4.61	To a great extent
Voice of customer	4.56	To a great extent
Modularity	4.22	To a considerable extent
Postponement	1.83	To a small extent
Supply chain responsiveness	4.09	To a considerable extent
NPD-SCM alignment	4.70	To a great extent
Competitive advantage	4.87	To a great extent

TABLE 6.21: Influence of linkages on NPD-SCM alignment - case study 2 (manufacturer)

Linkages	Priority vector	Degree of importance
Early supplier involvement	0.2403	Very High
Voice of customer	0.2403	Very High
Modularity	0.2403	Very High
Postponement	0.0385	Very low
Supply chain responsiveness	0.2403	Very High

TABLE 6.22: Influence of various factors on competitive advantage - case study 2 (manufacturer)

Factors	Priority vector	Degree of importance
Cost	0.1737	High
Quality	0.1746	High
Delivery	0.1385	Moderate
Flexibility	0.1273	Low
Innovation	0.2079	Very High
NPD-SCM alignment	0.1778	High

6.6 Case study 3- Dealer cum after sales service provider

The third and final case study was undertaken at the customer stage of the Indian automotive industry, i.e. dealer cum after sales service provider. The name of the company again has not been disclosed for the sake of confidentiality. However, a brief description about the company is given below.

6.6.1 Profile of the organization

The case organization is a dealer cum after sales service provider of a leading automobile manufacturing company. The manufacturing company is a wholly owned subsidiary of a major foreign automobile company that has a worldwide presence in 193 countries with annual production capacity of about 1.6 million vehicles, nearly 75,000 employees and approximately 6000 dealers over the globe. The company is also among India's three largest automobile manufacturers, and is the largest exporter of passenger cars from the country, contributing to nearly two-thirds of the total exports. It exports cars manufactured in India to 120 countries across Europe, Middle East, Latin America, Asia, Africa, and Australia. It has been manufacturing passenger cars in India for more than 15 years, and has two production facilities located in South India with an installed capacity of producing 630,000 units annually. The plants are having most advanced production, quality and testing capabilities in the country. At present, it offers 9 models of passenger cars and utility vehicles in Indian market, of which it manufacturers 7 models in India and imports 2 models from other countries. The company has also opened one research and development center located in a different city in South India.

In India, the company has a modest network of 346 dealers and 800 authorized service points across 340 cities. The case organization is one such company authorized dealer and after sales service center, located in a major city in North India. It was having a total work force of 46 employees in February 2013, with 26 technical staff members including supervisors for service / repair job, 12 marketing professionals, 5 persons for accounts and office work, and 3 persons as support staff. The annual sales in year 2012-13 were 1027 units amounting to 347 million INR (6.3 million USD), while the profit after tax was 11 million INR (0.2 million USD).

6.6.2 Results

The same methodology as used for the previous two case studies was adopted for data collection and analysis. Results are summarized in Tables 6.23 to 6.30.

TABLE 6.23: Pair-wise comparison matrices for NPD-SCM alignment and linkages

(a) NPD- SCM alignment

NPD- SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1/2	½	4	3	0.2152
Voice of customer	2	1	1	5	4	0.3109
Modularity	2	1	1	5	4	0.3109
Postponement	1/4	1/5	1/5	1	1/3	0.0474
Supply chain responsiveness	1/3	1/4	¼	3	1	0.1156

(b) Early supplier involvement

Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness	eVector
Voice of customer	1	1	1	3	0.3000
Modularity	1	1	1	3	0.3000
Postponement	1	1	1	3	0.3000
Supply chain responsiveness	1/3	1/3	1/3	1	0.1000

(c) Voice of customer

Voice of customer	Early supplier involvement	Modularity	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1	1	0.25
Modularity	1	1	1	1	0.25
Postponement	1	1	1	1	0.25
Supply chain responsiveness	1	1	1	1	0.25

(d) Modularity

Modularity	Early supplier involvement	Voice of customer	Postponement	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1	3	0.3000
Voice of customer	1	1	1	3	0.3000
Postponement	1	1	1	3	0.3000
Supply chain responsiveness	1/3	1/3	1/3	1	0.1000

(e) Postponement

Postponement	Early supplier involvement	Voice of customer	Modularity	Supply chain responsiveness	eVector
Early supplier involvement	1	1	1	3	0.3000
Voice of customer	1	1	1	3	0.3000
Modularity	1	1	1	3	0.3000
Supply chain responsiveness	1/3	1/3	1/3	1	0.1000

(f) Supply chain responsiveness

Supply chain responsiveness	Early supplier involvement	Voice of customer	Modularity	Postponement	eVector
Early supplier involvement	1	1	1	3	0.3000
Voice of customer	1	1	1	3	0.3000
Modularity	1	1	1	3	0.3000
Postponement	1/3	1/3	1/3	1	0.1000

TABLE 6.24: Un-weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2152	0	0.2500	0.3000	0.3000	0.3000
Voice of customer	0.3109	0.3000	0	0.3000	0.3000	0.3000
Modularity	0.3109	0.3000	0.2500	0	0.3000	0.3000
Postponement	0.0474	0.3000	0.2500	0.3000	0	0.1000
Supply chain responsiveness	0.1156	0.1000	0.2500	0.1000	0.1000	0

TABLE 6.25: Weighted super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2152	0	0.2500	0.3000	0.3000	0.3000
Voice of customer	0.3109	0.3000	0	0.3000	0.3000	0.3000
Modularity	0.3109	0.3000	0.2500	0	0.3000	0.3000
Postponement	0.0474	0.3000	0.2500	0.3000	0	0.1000
Supply chain responsiveness	0.1156	0.1000	0.2500	0.1000	0.1000	0

TABLE 6.26: Limit super-matrix for NPD-SCM alignment

NPD- SCM alignment	NPD-SCM alignment	Early supplier involvement	Voice of customer	Modularity	Postponement	Supply chain responsiveness
NPD-SCM alignment	0	0	0	0	0	0
Early supplier involvement	0.2219	0.2219	0.2219	0.2219	0.2219	0.2219
Voice of customer	0.2308	0.2308	0.2308	0.2308	0.2308	0.2308
Modularity	0.2219	0.2219	0.2219	0.2219	0.2219	0.2219
Postponement	0.2031	0.2031	0.2031	0.2031	0.2031	0.2031
Supply chain responsiveness	0.1224	0.1224	0.1224	0.1224	0.1224	0.1224

TABLE 6.27: Pair-wise comparison matrices for competitive advantage

(a) Competitive advantage

Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	1/3	1/2	2	6	1	0.1677
Quality	3	1	2	4	6	3	0.2940
Delivery	2	1/2	1	3	6	2	0.2244
Flexibility	1/2	1/4	1/3	1	5	1/2	0.1174
Innovation	1/6	1/6	1/6	1/5	1	1/6	0.0289
NPD-SCM alignment	1	1/3	1/2	2	6	1	0.1677

(b) Cost

Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Quality	1	2	3	5	3	0.3494
Delivery	1/2	1	2	5	2	0.2621
Flexibility	1/3	1/2	1	4	1	0.1705
Innovation	1/5	1/5	1/4	1	1/4	0.0474
NPD-SCM alignment	1/3	1/2	1	4	1	0.1705

(c) Quality

Quality	Cost	Delivery	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	2	7	6	4	0.3675
Delivery	1/2	1	6	5	3	0.2848
Flexibility	1/7	1/6	1	1/4	1/6	0.0317
Innovation	1/6	1/5	4	1	1/4	0.1032
NPD-SCM alignment	1/4	1/3	6	4	1	0.2128

(d) Delivery

Delivery	Cost	Quality	Flexibility	Innovation	NPD-SCM alignment	eVector
Cost	1	1	2	7	1	0.2603
Quality	1	1	2	7	1	0.2603
Flexibility	1/2	1/2	1	6	1/2	0.1844
Innovation	17	1/7	1/6	1	1/7	0.0346
NPD-SCM alignment	1	1	2	7	1	0.2603

(e) Flexibility

Flexibility	Cost	Quality	Delivery	Innovation	NPD-SCM alignment	eVector
Cost	1	1/2	1	4	1/2	0.1681
Quality	2	1	2	5	1	0.2641
Delivery	1	1/2	1	4	1/2	0.1681
Innovation	4	1/5	1/4	1	1/5	0.1357
NPD-SCM alignment	2	1	2	5	1	0.2641

(f) Innovation

Innovation	Cost	Quality	Delivery	Flexibility	NPD-SCM alignment	eVector
Cost	1	1/2	1/2	5	1/2	0.1777
Quality	2	1	1	6	1	0.2607
Delivery	2	1	1	6	1	0.2607
Flexibility	1/5	1/6	1/6	1	1/6	0.0403
NPD-SCM alignment	2	1	1	6	1	0.2607

(g) NPD-SCM alignment

NPD-SCM alignment	Cost	Quality	Delivery	Flexibility	Innovation	eVector
Cost	1	1/4	1/4	1	6	0.1600
Quality	4	1	2	4	7	0.3381
Delivery	4	1/2	1	4	7	0.3106
Flexibility	1	1/4	1/4	1	6	0.1600
Innovation	1/6	1/7	1/7	1/6	1	0.0305

TABLE 6.28: Un-weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1677	0	0.3675	0.2603	0.1681	0.1777	0.1600
Quality	0.2940	0.3494	0	0.2603	0.2641	0.2607	0.3389
Delivery	0.2244	0.2621	0.2848	0	0.1681	0.2607	0.3106
Flexibility	0.1174	0.1705	0.0317	0.1844	0	0.0403	0.1600
Innovation	0.0289	0.0474	0.1032	0.0346	0.1357	0	0.0305
NPD-SCM alignment	0.1677	0.1705	0.2128	0.2603	0.2641	0.2607	0

TABLE 6.29: Weighted super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1677	0	0.3675	0.2603	0.1681	0.1777	0.1600
Quality	0.2940	0.3494	0	0.2604	0.2641	0.2607	0.3389
Delivery	0.2244	0.2621	0.2848	0	0.1681	0.2607	0.3106
Flexibility	0.1173	0.1705	0.0317	0.1844	0	0.0402	0.1600
Innovation	0.0289	0.0474	0.1032	0.0346	0.1356	0	0.0305
NPD-SCM alignment	0.1677	0.1706	0.2128	0.2603	0.2641	0.2607	0

TABLE 6.30: Limit super-matrix for competitive advantage

Competitive advantage	Competitive advantage	Cost	Quality	Delivery	Flexibility	Innovation	NPD-SCM alignment
Competitive advantage	0	0	0	0	0	0	0
Cost	0.1994	0.1994	0.1994	0.1994	0.1994	0.1994	0.1994
Quality	0.2325	0.2325	0.2325	0.2325	0.2325	0.2325	0.2325
Delivery	0.2105	0.2105	0.2105	0.2105	0.2105	0.2105	0.2105
Flexibility	0.1121	0.1121	0.1121	0.1121	0.1121	0.1121	0.1121
Innovation	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615
NPD-SCM alignment	0.1839	0.1839	0.1839	0.1839	0.1839	0.1839	0.1839

6.6.3 Findings

Table 6.31 shows the extent to which all the variables were being practiced in the firm. The results showing the priority vectors of key linkages influencing NPD-SCM alignment, their significance as well as possible reasons, have been summarized in Table 6.32. Similarly, priority vectors of various factors influencing competitive advantage, their implications and possible causes have been presented in Table 6.33.

TABLE 6.31: Visibility of variables in case company 3 (dealer)

Variable	Average rating (out of 5)	Degree to which variable is present
Early supplier involvement	4.17	To a considerable extent
Voice of customer	4.00	To a considerable extent
Modularity	3.33	To a moderate extent
Postponement	4.33	To a considerable extent
Supply chain responsiveness	2.67	To a moderate extent
NPD-SCM alignment	3.17	To a moderate extent
Competitive advantage	4.00	To a considerable extent

TABLE 6.32: Influence of linkages on NPD-SCM alignment for case study 3 (dealer)

Linkages	Priority vector	Degree of importance
Early supplier involvement	0.2219	High
Voice of customer	0.2308	High
Modularity	0.2219	High
Postponement	0.2031	High
Supply chain responsiveness	0.1224	Low

TABLE 6.33: Influence of various factors on competitive advantage for case study 3 (dealer)

Factors	Priority vector	Degree of importance
Cost	0.1994	High
Quality	0.2325	Very High
Delivery	0.2105	Very High
Flexibility	0.1121	Low
Innovation	0.0615	Very Low
NPD-SCM alignment	0.1839	High

The findings of each case study were discussed with the executives of that company with the objective of exploring possible reasons behind the outcome. These discussions were beneficial in comprehending the concepts of the study, as well as the role of research variables at each stage of the automotive supply chain. In some cases, even the company professionals admitted that the findings helped them in developing deeper understanding about their own organization. These discussions underlying the differential behavior of research variables across various supply chain stages are presented in the next chapter.

CHAPTER 7

DISCUSSION AND CONCLUSION

7.1 Introduction

Findings of the large-scale survey highlight the importance of various linkages in affecting NPD-SCM alignment, as well as the competitive priorities that should be adopted by firms in Indian automotive industry. But are these observations universally applicable to the entire Indian automobile industry, or just an outcome of some mathematical analysis? Are there any reasons which can justify these numerical expressions? Can these results be generalized for all the stages of Indian automobile industry, or do they need to be modified differentially according to the varying local conditions across different supply chain stages? These questions must be answered in order to validate the findings of the study, prior to generalizing them in context of Indian automotive industry. For the purpose, in-depth discussions were held with executives of all the three case companies. These discussions helped in exploring possible reasons for variations in the degree of influence of research variables on NPD-SCM alignment and competitive advantage.

In the forthcoming sections, first these reasons have been discussed for each stage of the automotive supply chain. Then the findings of all the three case studies have been compared with each other, as well as with the findings of the large scale survey, and conclusions have been drawn indicating the contribution made by the research. Finally, some potential areas for future research have been suggested.

7.2 Case study 1- Supplier

Table 6.1 has been reproduced again as Table 7.1, which shows the extent to which all the variables are being practiced in the firm.

TABLE 7.1: Visibility of variables in case company 1 (supplier)

Variable	Average rating (out of 5)	Degree to which variable is present
Early supplier involvement	3.18	To a moderate extent
Voice of customer	4.64	To a great extent
Modularity	4.19	To a considerable extent
Postponement	2.36	To a small extent
Supply chain responsiveness	4.00	To a considerable extent
NPD-SCM alignment	4.00	To a considerable extent
Competitive advantage	4.09	To a considerable extent

The results showing the priority vectors of key linkages influencing NPD-SCM alignment computed through ANP, their significance, as well as possible reasons are summarized in Table 7.2.

TABLE 7.2: Influence of linkages on NPD-SCM alignment for case study 1 (supplier)

Linkages	Priority vector	Degree of importance	Reasons
Early supplier involvement	0.1943	Moderate	Product design is provided by customer, so NPD activities are not very high
Voice of customer	0.2467	Very High	Specifications provided by customer, even alterations need customer approval
Modularity	0.2189	High	Most of the processes are standardized so process modularity is high.
Postponement	0.1340	Low	Mostly the entire process starts after getting order, little scope for mass customization
Supply chain responsiveness	0.2062	High	Focus on cost reduction, timely delivery, volume flexibility, and lead time reduction

TABLE 7.3: Influence of various factors on competitive advantage for case study 1 (supplier)

Factors	Priority vector	Degree of importance	Reasons
Cost	0.1716	High	Quality and design being fixed by the customer, the competition is mainly on cost and prompt delivery
Quality	0.1019	Low	Quality levels are already high, and since specifications are given by the customers, there is hardly any scope of any variation in quality levels
Delivery	0.1895	High	Customers are big companies and so deadlines are important, prompt delivery from suppliers is crucial
Flexibility	0.1640	High	Variations in design / volume , uncertainties in production environment
Innovation	0.1443	Moderate	Design mostly provided by customer, hence NPD efforts are only moderate
NPD-SCM alignment	0.2286	Very high	Whenever a new order is received, a high degree of coordination with supply chain partners is needed before making any commitment to the customer

The priority vector of each linkage represents its contribution in improving NPD-SCM alignment for the case company. It can be observed from Table 7.2 that the contribution of voice of customer is highest (0.2467), followed by that of modularity (0.2189). Supply chain responsiveness (0.2062) and early supplier involvement (0.1943) also appear to be important contributors, but contribution of postponement (0.1340) is relatively low in comparison. Similarly, priority vectors of various factors influencing competitive advantage, their implications and possible causes have been presented in Table 7.3. Among the factors, the influence of NPD-SCM alignment is found to be very high (0.2286), followed by high importance of cost (0.1716) and delivery (0.1895) and flexibility (0.1640). The influence of innovation (0.1443) is moderate, while that of quality (0.1019) is low.

The findings of the case study were discussed with senior management of the case organization, and summary of the discussion is presented below.

7.2.1 Linkages influencing NPD-SCM alignment

The results exhibit that for the case company, the influence of linkages on NPD-SCM alignment varies according to nature of the firm, its business environment, and local conditions. The effect of each linkage is discussed below.

7.2.1.1 Early supplier involvement

The case firm offers very large product variety with frequent changes in design. The design is normally provided by the customer firms in form of specifications, with only a little scope of modification. Only the production process has to be designed by the company executives. Generally the same raw material is required for manufacturing different designs and therefore, the suppliers are usually limited and fixed. Raw material is ordered in bulk to exploit the economies of scale. In such a scenario, the need for supplier involvement during new product development is not very high. Recall that ESI is being practiced in the case firm to a moderate extent only (3.18), in comparison to all other linkages. Further, ESI is correlated with other linkages such as VOC and modularity. Thus ESI has a moderate influence (0.1943) on NPD-SCM alignment for the case firm.

7.2.1.2 Voice of customer

Voice of customer is definitely important in today's competition, with customer satisfaction holding the key to success. As mentioned earlier, product design is generally provided by the customer in form of specifications, and is more-or-less fixed. The process has to be planned to produce products as per customer specification, and in case of any trade-off situation, any alteration in product design is possible only after approval of the customer. Hence, there is a high degree of interaction with customers during NPD process. This is supported by the observation that VOC was found to be practiced in the case firm to a great extent (4.64). Voice of customer was also found to influence some other linkages such as early supplier involvement, modularity and supply chain responsiveness. Hence, voice of customer has a very high influence (0.2467) on NPD-SCM alignment for the case firm.

7.2.1.3 Modularity

Modularity is one of the most effective strategic design options for increasing product variety and at the same time, keeping the costs low. The company already practiced modularity to a considerable extent (4.19) in order to produce a wide variety of design. Most of the processes have been standardized and hence process modularity is quite high. Thus, its contribution in improving NPD-SCM alignment is found to be high (0.2189). Modularity also affects VOC, postponement and SCR, and thus this indirect contribution increases its score in the ANP model.

7.2.1.4 Postponement

These days, postponement has emerged as an effective way of offering mass customization, in which most of the production is completed as per production schedule, but the final assembly is postponed until getting customer order. The parts are produced in bulk to exploit economies of scale as per anticipated demand, but are assembled as per customer preferences. However, the nature of case firm is such that there is limited scope for postponement. Although the company offers a wide product range with frequent design changes, the orders are received well in advance, and the company has to manufacture the products as per the specifications laid down by the customer. The company is working in a make-to-order environment and almost the entire process starts after the customer order is received; hence there is hardly any scope for postponement. That was the reason it was found to be practiced in the case firm to a small extent (2.36). Its influence on NPD-SCM alignment is limited, and thus its priority vector came out to be the least (0.1340), quite low in comparison to the remaining linkages.

7.2.1.5 Supply chain responsiveness

Supply chain responsiveness is the flexibility of the entire supply chain to adapt quickly to changes in design and quantity. It was also observed to be practiced in the case firm to a considerable extent (4.0). The case firm has multiple plants clustered together. Any variations in product design and volume are met by re-allocating raw material and labor between the plants, and transporting them quickly among each other. Thus, supply chain responsiveness has a high influence (0.2062) on NPD-SCM alignment. However, it is influenced by almost all other linkages to a significant extent, and consequently, in the ANP model, its priority vector got marginally reduced, transferring some of its weight age to other linkages due to their indirect influence.

NPD-SCM alignment was visible in the case company to a considerable extent (4.0). The company was also practicing most of the linkages except postponement, to a considerable extent. Thus, the executives were well aware of these concepts and therefore, their opinion could be considered as reliable and relevant, thereby assuring the validity of results.

7.2.2 Competitive priorities

Competitive advantage of the case company has been rated by its executives to a considerable extent (4.09). The priority vectors of various competitive priorities indicate their relative importance in improving competitiveness. Each priority vector indicates the relative importance of controlling a factor in improving competitiveness. It does not measure the absolute importance of any factor, but indicates the relative weight age of varying the factor for enhancing competitive advantage. For example, a low value of priority vector of quality does not mean that quality is not an important factor, but it indicates that variation in quality level would not result in any significant gains in competitive advantage for the company; maybe because quality level is already very high, or increasing quality level further would require a tremendous increase in cost, which would adversely affect competitiveness. The findings were discussed with company executives to explore possible reasons behind variation in degree of importance among the factors. The salient points of the discussion are presented below.

7.2.2.1 Cost

In order to cut down the cost of automobiles, nearly all manufacturers are looking for suppliers that can supply parts at cheaper rates. A supplier who can supply the same quality part at a lower cost is more competitive and hence successful. The suppliers are usually much smaller in comparison to the automobile companies, and for them reduction in production and supply costs reflects directly in their profits. Thus, cost is having a high value of priority vector (0.1716), and it turns out to be an important competitive priority for the case company.

7.2.2.2 Quality

Most of the automobile companies operating in India are multi-national companies, and some even export vehicles produced in India to other countries. As a consequence, quality level is quite high across the entire automotive supply chain in general. The case firm supplies automotive lighting equipments to major automobile companies in domestic as well as export market, which have stringent and high quality norms. Further, as mentioned before, the specifications of the products are provided by the automobile manufacturers. Hence, design as well as quality of the products are more or less fixed by the manufacturers, and are invariably high. Also since the company caters to export market also, the quality of raw materials, finished products, as well as production process has to meet global standards. There is hardly any scope of any variation in quality levels. Thus for the case company, the priority vector of quality

(0.1019) came out to be low.

7.2.2.3 Delivery

Customers of the case firm are big automobile companies which have a large number of vendors supplying different automobile parts / components. In order to cut down cost, big automakers try to carry minimum inventory themselves by adopting strategies such as lean manufacturing, vendor managed inventory, and just in time. In such a scenario, prompt and dependable delivery from suppliers is a crucial decision factor, and vendors who can ensure dependable delivery gain competitive advantage over rivals. The same is true for the case company, and consequently the priority vector for delivery comes out to be high (0.1895).

7.2.2.4 Flexibility

Flexibility is usually considered an important competitive priority. Production environment is usually characterized by frequent variations in design / volume, machine breakdowns, labour shortage, and other uncertainties. There is always some fluctuation in demand and thus last minute changes in the production process. The core company also experiences these effects and as a result flexibility finds a high importance (0.1640) in the case firm.

7.2.2.5 Innovation

Since design is generally provided by the customer, in-house NPD efforts are minimum. The process is almost the same for any design, and consequently even the plant layout is more or less fixed. Production is usually done in lots as per the varying customer orders. The supplier is a mid-sized organization, with moderate resources. In such scenario, the expenditure on innovation is not much. Therefore, the influence of innovation on competitive advantage of the case firm also comes out to be moderate (0.1443).

7.2.2.6 NPD-SCM alignment

A large number of parts are used in manufacturing an automobile. The automotive supply chain is often quite big and complex, with a large number of suppliers, manufacturers, and customers. A high degree of coordination is required between the supply chain partners, especially whenever any new product has to be launched, or in case of design alterations. Thus alignment between new product development and supply chain management activities is perceived to have a powerful influence on competitiveness. For the case company, whenever a new order is received, a high degree of coordination with supply chain partners is needed before making any commitment to the customer regarding cost, quality, and delivery of the product. For this reason, the influence of NPD-SCM alignment on competitive advantage of the case company has come out to be very high (0.2286). Further, with quality and design being fixed by the customer, the competition of the case company with its rivals is mainly on cost and prompt delivery, both of which are heavily dependent on NPD-SCM alignment.

7.3 Case study 2- Manufacturer

The visibility of all the variables in the firm is shown in Table 7.4. The results of ANP showing the priority vectors of key linkages influencing NPD-SCM alignment along with their significance and possible reasons are summarized in Table 7.5. Similarly, priority vectors of various factors influencing competitive advantage, their implications and possible causes have been presented in Table 7.6.

TABLE 7.4: Visibility of variables in case company 2 (manufacturer)

Variable	Average rating (out of 5)	Degree to which variable is present
Early supplier involvement	4.61	To a great extent
Voice of customer	4.56	To a great extent
Modularity	4.22	To a considerable extent
Postponement	1.83	To a small extent
Supply chain responsiveness	4.09	To a considerable extent
NPD-SCM alignment	4.70	To a great extent
Competitive advantage	4.87	To a great extent

TABLE 7.5: Influence of linkages on NPD-SCM alignment for case study 2 (manufacturer)

Linkages	Priority vector	Degree of importance	Reasons
Early supplier involvement	0.2403	Very High	Required for high innovation, frequent design changes, cost reduction
Voice of customer	0.2403	Very High	Company tries to introduce new features that address customer needs
Modularity	0.2403	Very High	Large no. of parts, cost reduction, effective in introducing variants
Postponement	0.0385	Very low	Absence of mass customization in automotive industry
Supply chain responsiveness	0.2403	Very High	Large no. of components, effective in reducing lead time

TABLE 7.6: Influence of various factors on competitive advantage for case study 2 (manufacturer)

Factors	Priority vector	Degree of importance	Reasons
Cost	0.1737	High	Cost has always been an important factor in Indian market, specially for entry-level passenger car segment
Quality	0.1746	High	With a lot of MNCs in India, competition has taken quality to global standards, quality is also important for exports
Delivery	0.1385	Moderate	Company already has large production and distribution capabilities sufficient for reliable, timely and dependable delivery
Flexibility	0.1273	Low	Company uses dedicated assembly lines for production, the sequence of operations is usually fixed in a line, predictable demand forecasts, make-to-stock environment
Innovation	0.2079	Very High	Introduction of new features / design has the highest influence on sales, company is leader in introducing new models
NPD-SCM alignment	0.1778	High	Large no. of components and suppliers, importance of cost, quality and innovation necessitate a high degree of NPD-SCM alignment

It can be seen from Table 7.4 that according to the perception of company executives, both NPD-SCM alignment and competitive advantage exist to a great extent. Among the linkages influencing NPD-SCM alignment, early supplier involvement and voice of customer are visible to a great extent, while modularity and supply chain responsiveness are present to a considerable extent. However, postponement has been found to exist only to a small extent. Table 7.5 shows that for the case company, the influence of all the linkages on NPD-SCM alignment is very high, except for postponement which is very low. Finally, it can be observed from Table 7.6 that innovation, cost, quality, and NPD-SCM alignment are important competitive priorities for the case firm.

The findings of the case study were discussed with senior management of the case organization. Summary of the discussion for all the linkages and competitive priorities is presented below.

7.3.1 Linkages influencing NPD-SCM alignment

The priority vectors exhibit that for the core company, influence of linkages on NPD-SCM alignment vary according to local conditions. The possible reasons behind varying impact of linkages on NPD-SCM alignment were explored through in-depth discussion with company executives, and are presented below.

7.3.1.1 Early supplier involvement

The company is at present manufacturing 15 different models with more than 200 variants. A large number of parts / components / sub-systems go into the assembly of these automobiles. Whenever a new model has to be introduced, or some design changes are to be made for a facelift of existing model, or few features are to be introduced to develop a new variant, these are possible only if the suppliers are ready to make alterations in their production system to supply the parts / components / sub-systems to match the planned changes. There is no point in designing a vehicle whose parts / components cannot be supplied by the vendors. Even for existing models, the cost of supplies can be reduced significantly if the design is developed in coordination with the suppliers. Therefore, involvement of suppliers early during NPD efforts is crucial for innovation as well as cost reduction. In fact, the case company has a separate vendor development unit which works in collaboration with the suppliers on the design of components and sub-systems. Thus, early supplier involvement is visible in the case company to great extent (4.61) and its influence on NPD-SCM alignment is very high (0.2403).

7.3.1.2 Voice of customer

Automotive industry is characterized by a high degree of innovation. Most companies are fuelling their R&D efforts to come up with some new features for attracting more and more customers. While developing new products, the case company regularly seeks feedback from its customers through its vast network of dealers and service centers to capture customer preferences. The company also seeks opinion and advice from automobile experts, and takes a note of the articles published in automotive magazines, journals, and newspaper. It also participates in surveys and contests conducted by independent bodies such as JD Power, Autocar, etc. Hence, voice of customer is considered important by the company, and is therefore practiced to a great extent (4.56). VOC also increases communication between various stages of the supply chain in the process of passing customers' opinion upstream. When the company receives some useful customer feedback from its dealers, it gives some incentives in return. The entire process results in improving business relations and coordination between supply chain partners. Hence in the case company, the influence of voice of customer on NPD-SCM alignment is very high (0.2403).

7.3.1.3 Modularity

Most auto makers try to offer more and more models and variants in order to enable customers to choose from a wider product range. A wider product range not only offers options in terms of design features, but also increases the price band, and hence attracts a larger number of customers who can choose as per their preferences and budget. Increasing product range usually calls for a rise in cost, but modularity can be used for providing more variety at minimum additional cost. As mentioned earlier, there are 15 models and over 200 variants manufactured by the case company. The company's NPD team has divided an automobile into a number of sub-systems or modules which are functionally self-sufficient, and can be assembled to form the complete automobile. Some of these modules are produced in-house, but a larger number are generally procured from suppliers, who have to be involved early during design and planning phase of that module. These modules are usually made inter-changeable and can be assembled in a number of combinations, resulting in a variety of models and variants. For example, the company has inter-changed the module 'manual steering' with 'power steering' to develop an additional variant of an existing model. In some cases, extra or optional modules can be added to the base model for creating a new variant. For example, new variants have been developed by adding extra modules such as 'audio system' or 'air bag' to the base model. In some cases the company is using common modules such as 'engine' or 'transmission system' for many different models, thereby cutting tremendous cost of designing and producing separate modules for each model. The company also uses the strategy of developing two or more cars on a common platform, on which different modules can be inter-changed. Thus, modularity is being used in the case company to a considerable extent (4.22), and its influence on NPD-SCM alignment also has come out to be very high (0.2403).

7.3.1.4 Postponement

Another strategy of offering more variety without affecting the cost is postponement, in which components mostly in form of modules are produced earlier, but are assembled later as per customer preferences. It differs from modularity in that the parts / components, whether in form of modules or otherwise, are assembled only after getting customer order; while in case of modularity, the sub-systems are essentially developed as independent modules, but their assembly has no connection with the timing of receiving customer order. The concept of mass customization is yet to emerge in Indian market. Hardly one or two foreign companies manufacture cars as per customer order, and that too once a while. Almost all automakers are producing cars in a make-to-stock environment, with production schedules designed to match demand forecasts. The case company like most other manufacturers is having plant layout in form of long assembly lines. The components / modules are assembled on the vehicle body /

chassis as it moves forward on the assembly line, and the complete vehicle comes out at the end. The vehicles are stored in sheds and parking lots from where they are transported to the dealers. Since the dealers and customers are located far off, vehicles cannot be customized according to their preferences. Further, as mentioned before, the case company produces approximately one million vehicles annually, which is an indicator that demand of company's cars is already very high-- in fact some of the models are having a booking period of 3 to 6 months. It also offers a high variety in terms of 15 models and 200 variants. In such a scenario, there is no need for the company to go for postponement. Hence, it is found to be practiced in the case company only to a small extent (1.83), and consequently, its impact on NPD-SCM alignment is very low (0.0385).

7.3.1.5 Supply chain responsiveness

An automobile consists of a large number of parts and sub-assemblies that are supplied by a large number of ancillary companies and vendors. The case company has a vast network of dealers and authorized service centers where it supplies vehicles and spare parts. Such a large number of partners in form of tier-1 and tier-2 suppliers, dealers and service centers, with hundreds of components, and over 200 variants of vehicles make the supply chain quite complex, thereby requiring a high level of supply chain responsiveness. Working on the strategy of providing affordable vehicles in the entry level car segment, the company follows principles of lean management and vendor managed inventory. This further necessitates the supply chain to be more responsive in order to ensure timely supplies of components, automobiles and spares, as well as absorb fluctuations in a highly dynamic business environment. This is substantiated by the presence of supply chain responsiveness to a considerable extent (4.09). In order to maintain the high market share, the case company follows a strategy of frequently introducing new models or face-lifting existing ones by adding some innovative features. It incurs considerable expenditure on NPD activities to develop these innovative features faster than its rivals. Lead time reduction is an important consideration during NPD activities, and is deeply affected by supply chain responsiveness. Thus, in order to minimize lead times, the company is having a responsive supply chain which has a very high influence on NPD-SCM alignment (0.2403).

7.3.2 Competitive priorities

India has a large middle-class population and is typically a cost sensitive market. An increase in buying capacity of the middle class has been an important reason for increase in the sale of automobiles in India. With many automobile companies entering the Indian market, more and more options are available for the customer, thereby increasing competition among manufacturers. The findings of the case study were discussed with company executives to explore possible reasons behind variation in degree of importance among the competitive priorities. The salient points of the discussion are presented below.

7.3.2.1 Cost

The average income level in India is much lower than that in developed countries, and thus in order to attract more and more customers, most automakers are trying to cut down the cost of their vehicle so that it comes in reach of more and more people. The case company has a clear strategy of targeting entry-level segment of the domestic passenger car market, which continues to be cost sensitive even today. Most of the company's models are priced slightly less than the competing models of rival companies. The company has been operational in Indian market for nearly 30 years, and therefore has a pretty good understanding of customer preferences. Cost has always been and is still an important competitive priority for the case company, and thus its priority vector comes out be high (0.1737).

7.3.2.2 Quality

With the entry of many multi-national companies having global supply chains, quality in Indian automotive industry has experienced a significant improvement. Some of these companies are also exporting vehicles produced in India to other foreign countries, thereby further elevating the quality standards. Majority of automakers are making continuous efforts for further improving their quality levels in order to meet ever increasing customer expectations. Thus, quality is undoubtedly an important competitive priority for most manufacturers, especially those in export sector. The case company is having collaboration with a reputed foreign automaker having presence in all major markets of the world, and is even exporting some of its models produced in India to other parts of the world. The company initially had an advantage of early start in Indian market, but has been facing a fierce competition from major automakers of the world since the last decade or so. In order to remain competitive, the case company is focusing on total quality improvement, through continuous research and development, vendor development, and quality certifications. Thus quality is considered an important competitive priority by company’s top management, and hence its priority vector has come out to be high (0.1746).

7.3.2.3 Delivery

The case company has been operational in domestic market for nearly 30 years, much longer than most of its rivals. It is thus well aware of the business environment in the country. Over the years, it has identified good and reliable suppliers, and developed strong business relations and agreements with them. The company is also having a large production capacity of manufacturing over a million cars a year in India, as well as a large and strong network of 1204 dealers and nearly 2976 service centres across the country. Due to these factors, the case company is at present having production and distribution capabilities sufficient to ensure reliable, timely and dependable delivery, and is much ahead of its competitors in this regard. Since delivery is already quite high, the company's management is focusing more on other areas for improving competitive advantage, and as a result the weight age given to delivery as a competitive priority is only moderate (0.1385).

7.3.2.4 Flexibility

As mentioned earlier, the company's plants are having fixed layout in form of long assembly lines, with component and modules being assembled to the body / chassis as the automobile moves along the shop floor. There are separate assembly lines for different models. Hence, flexibility is limited, as can be expected in case of mass production having product layout. The installed production capacity is very large and there is no resource limitation. Due to its long presence in domestic market, the company is having a pretty good understanding of market dynamics, demand pattern and customer behaviour. It has been able to maintain a high market share with fairly reliable forecasts. The company is working in a make-to-stock environment, and has no immediate plans of offering mass customization. Thus under these circumstances, for the case company, the importance of flexibility as a competitive priority is low (0.1273).

7.3.2.5 Innovation

The entry of a large number of global automobile companies in India, especially during the last decade, has resulted in a tremendous increase in the variety of vehicles in the market. This has made customers more powerful who are now in a position to select automobiles of their choice from among multiple options available to them. Their choice is influenced among other factors, by the number and type of features, ergonomics, appealing design and aesthetics. Consequently most manufacturers are trying to please customers through innovative design and / or features. Research and development teams are focusing on innovation both during new product development as well as for upgrading existing models. The case company is a trend-setter in Indian automotive market in terms of developing new models and variants. Over the last 30 years, it has introduced 23 different models with many variants. Out of these, 8 models have been discontinued, while 15 models are still on road. During the last five years, it has launched 9 models and all of them are still in market. The company has set up a separate R&D facility in north India with a world class infrastructure spread on 600 acres and more than 1200 engineers. It also supports and participates in R&D activities in collaboration with prestigious bodies like Society of Automotive Engineers (SAE) and Society of Indian Automobile Manufacturers (SIAM). At present the company is working on new technologies such as vehicle weight reduction, improving fuel efficiency, alternate materials and fuels, reducing emissions, etc. Thus, the company gives a very high priority to innovation (0.2079) for improving competitive advantage.

7.3.2.6 NPD-SCM alignment

Indian automotive supply chain is characterized by a large number of components, automobiles, suppliers, manufacturers, and dealers having complex interactions under dynamic business environment. Effective supply chain management is required for smooth coordination among various partners in such a big supply chain, particularly for NPD activities which are very important for getting competitive advantage. Thus NPD-SCM alignment is a major competitive priority for most automobile manufacturers. The case company is one of the largest automobile companies in India. Its manufacturing capacity, product range and distribution network are also among the largest in the country. Innovation, quality and cost are important competitive priorities for the company. Under these circumstances both NPD and SCM activities are important, and proper alignment between the two is critical for the success of the company. The company has a proper understanding of the capabilities and constraints of its major supply chain partners, and involves them in NPD activities. The goals for the NPD activities are mostly framed in consultation with them. The company and its supply chain partners have clearly defined responsibilities, and share the costs and benefits of NPD activities. Thus the company considers NPD-SCM alignment as an important tool for improving competitive advantage, and gives it a high priority (0.1778).

7.4 Case study 3- Dealer cum after sales service provider

The degree of visibility of all the variables in the company is shown in Table 7.7. The results of ANP showing the priority vectors of key linkages influencing NPD-SCM alignment along with their significance and possible reasons are presented in Table 7.8. Similarly, priority vectors of various factors influencing competitive advantage, their implications and possible causes have been presented in Table 7.9.

TABLE 7.7: Visibility of variables in case company 3 (dealer)

Variable	Average rating (out of 5)	Degree to which variable is present
Early supplier involvement	4.17	To a considerable extent
Voice of customer	4.00	To a considerable extent
Modularity	3.33	To a moderate extent
Postponement	4.33	To a considerable extent
Supply chain responsiveness	2.67	To a moderate extent
NPD-SCM alignment	3.17	To a moderate extent
Competitive advantage	4.00	To a considerable extent

TABLE 7.8: Influence of linkages on NPD-SCM alignment for case study 3 (dealer)

Linkages	Priority vector	Degree of importance	Reasons
Early supplier involvement	0.2219	High	Consent of suppliers / manufacturers is required before making any major changes in process and in product mix
Voice of customer	0.2308	High	Choice / requirement of customers is most important in both NPD and repair jobs
Modularity	0.2219	High	Process modularity helps cutting cost and time during repair jobs, product modularity helps during assembly and repairs
Postponement	0.2031	High	Most operations start after customer arrives
Supply chain responsiveness	0.1224	Low	Absence of NPD and production activities, orders placed as per demand patterns, reliable delivery of supplies

TABLE 7.9: Influence of various factors on competitive advantage for case study 3 (dealer)

Factors	Priority vector	Degree of importance	Reasons
Cost	0.1994	High	Cost of vehicle is fixed by the manufacturer, however discounts, promotions, accessories, free service are used to attract customers
Quality	0.2325	Very High	The company attributes high quality of products and service as the biggest factor for its success
Delivery	0.2105	Very High	Timely delivery of new cars and repair jobs is very important
Flexibility	0.1121	Low	Company gets the supply of vehicles and spare parts as per order, design / volume flexibility not required, only in-house flexibility required during repair or emergency order
Innovation	0.0615	Very Low	Absence of any design activity, use of standard tools, equipment and procedures
NPD-SCM alignment	0.1839	High	Important stage of supply chain for communicating voice of customer upstream for NPD activities of supply chain partners

It can be seen from Table 7.7 that while the case company feels that it is having competitive advantage to a considerable extent (4.00), NPD-SCM alignment is present to a moderate extent only (3.17). This is primarily due to the fact that the case company is a dealer cum service center of a major automobile company, and there is hardly any scope of NPD activities in the case firm itself. Its participation in the NPD activities of the manufacturer is limited mainly to passing on the voice of customer upstream the supply chain. Among the linkages influencing NPD-SCM alignment, early supplier involvement, voice and customer and postponement are visible in the case company to a considerable extent, while modularity and supply chain responsiveness are present to a moderate extent only. The influence of all the linkages on NPD-SCM alignment is high, except for supply chain responsiveness which is low. Quality and delivery are the most important competitive priorities for the case company, followed by cost and NPD-SCM alignment.

The findings were discussed with senior executives of the organization. Summary of discussion on varying effect of linkages and competitive priorities is presented below.

7.4.1 Linkages influencing NPD-SCM alignment

The findings show that for the core company, impact of linkages on NPD-SCM alignment vary according to the nature of the firm, its business environment, and local conditions. The possible reasons behind varying impact of linkages on NPD-SCM alignment were explored through in-depth discussion with company executives, and are presented below.

7.4.1.1 Early supplier involvement

The case company is a dealer cum service center of a big automobile manufacturer. Its main activities include selling various models and variants of automobiles, and doing service and repair jobs for its customers. Therefore, there is hardly any NPD activity being performed directly by the case company. Some improvements are sometimes made in the process, such as layout changes in workshops and job sequence, introduction of promotional schemes for customers, special services offered to existing customers, etc. But these changes have to be approved by the manufacturer. For making any changes in product mix, manufacturer and part suppliers have to be consulted to ensure proper supplies. In case of some high demand models, there is a waiting period of 2 to 3 months before the vehicle can be supplied to the customer. In such cases, the company has to coordinate with upstream supply chain members before making any commitment about delivery at the time of booking. The same has to be done for replacement parts and accessories suppliers also, in order to ensure high quality of after sales services. Thus, early supplier involvement is being practiced to a considerable extent (4.17), and its contribution in NPD-SCM alignment is also high (0.2219).

7.4.1.2 Voice of customer

The case company's participation in NPD activity is largely limited to sending customer feedback and preferences upstream to the manufacturer. The case company generally assesses customer requirements about design and quality of vehicles through formal feedback forms, as well as through verbal discussion. It also gauges the response of customers towards any new model or features introduced by the manufacturer. Thus, voice of customer is recorded to a considerable extent (4.00), and its contribution towards NPD-SCM alignment comes out to be quite high (0.2308) for the case company.

7.4.1.3 Modularity

The company usually receives completely assembled automobiles. The vehicles do have some modules or sub-assemblies, but use of modularity in the case company is not very high. It is used mainly during repair jobs in form of part replacement. For example, an entire module of 'clutch assembly' can be replaced, or an entire module of 'steering system' can be taken out for performing a denting job. But to allow this, the vehicle must be designed accordingly during NPD, and these modules must be available in the market through a number of suppliers. Thus, modularity improves NPD-SCM alignment of the supply chain. The entire workshop consists of many process modules, and service and repair jobs can be assigned to these modules independently, thereby improving process modularity. On the whole, modularity is present to a moderate extent (3.33) in the case company, and its contribution towards NPD-SCM alignment is high (0.2219).

7.4.1.4 Postponement

In the previous two case studies – i.e. supplier and manufacturer, postponement was found to be practiced to a small extent only. However, the third case company is a dealer and authorized service center, where most of the activities start after the customer order arrives. Procurement of automobiles and spare parts is done before receiving customer order, while most activities related to sale / service / repair commence on arrival of the customer. These activities are also customized according to the customer's need. For example, when a customer comes to purchase a new vehicle, a sales executive explains and demonstrates different features of various models, specials offers and schemes, finance options, etc. and thus helps the customer in placing order. When the order is placed, technicians make the automobile ready by adding accessories ordered by customer and performing pre delivery check. In case of repairs, a job card is prepared on customer's arrival, in which various works desired by the customer are listed which are later performed by various technicians and workers. Thus postponement is being practiced in the case company to a considerable extent (4.33) and its influence on NPD-SCM alignment is high (0.2031) for the case company.

7.4.1.5 Supply chain responsiveness

The case company is the last stage of the supply chain, where finished vehicles are sold to individual customers, and service / repair jobs are done. Both NPD and manufacturing activities are almost absent, and consequently a high degree of supply chain responsiveness is usually not needed. The case firm places orders well in time for models having high and stable demand, and since it is an authorized outlet of a big automobile manufacturer, the supplies of vehicles and spare parts are generally reliable. The high priced models and slow moving items are procured only after these are booked by the customer. In such cases, usually the customer is ready to wait for a certain time before getting delivery. For this reason, supply chain responsiveness is present to a moderate extent (2.67) only and its influence on NPD-SCM alignment comes out to be low (0.1224) in comparison to other linkages.

7.4.2 Competitive priorities

The findings were discussed with company executives to explore possible reasons behind variation in degree of importance among the competitive priorities. The salient points of the discussion are presented below.

7.4.2.1 Cost

Since the case company is an authorized outlet of a leading automobile manufacturer, the pricing of various models, spare parts, repairs, etc. are usually fixed by the manufacturer. Even special offers during festive season are floated by the manufacturer. In such a scenario, the case company does not have much control over pricing. However, in order to gain competitive advantage, it offers some additional discounts and some free accessories to attract the customer. It also organizes free check up and service camps time to time with some discounts on spare parts as well. Thus cost is considered as an important competitive priority (0.1994) by the case company.

7.4.2.2 Quality

One of the main competitive strategies of the manufacturer is to offer automobiles having better quality levels at comparative or slightly higher price than most of the competitors. The policy of superior quality is further strengthened in the case company by providing high quality service to its customers in form of after sales support, repairs, attending complaints, etc. In fact the company considers quality of its products and services as the biggest factor for its success, and consequently, its priority vector (0.2325) indicates that quality has a very high impact on competitive advantage.

7.4.2.3 Delivery

Another important factor behind the success of the entire group is prompt and reliable delivery. The company is very particular about its promise made to the customers at the time of booking. The case company has installed sophisticated modern equipment in its workshop to ensure timely delivery of repair and service jobs. The company has a good reputation of adhering to the deadlines, and hence, the effect of delivery on competitive advantage is very high (0.2105).

7.4.2.4 Flexibility

In absence of any production activity, the operations in case firm are usually quite stable with hardly any disturbances. The case company does not need to bother about changes in product design or volume, typical of a production environment. With a reliable logistic system to ensure timely delivery, the supply of vehicles and spare parts are also smooth. There are few fluctuations that the company experiences in form of some emergency orders, for which it keeps a margin through mutual coordination with other dealers in vicinity. Thus flexibility is not a very important factor, except during repair jobs. Within the workshop, there is enough flexibility in equipment and workforce to make alterations in daily schedules in order to expedite emergency orders. On the whole, the influence of flexibility on competitive advantage is low (0.1121).

7.4.2.5 Innovation

Most of the tools and equipment in the case company are standard, and are procured through the manufacturer in order to ensure uniformity in repairs across the country. There is hardly any scope of design activity at the level of the case firm – only some improvisation in jigs and fixtures are carried out once a while. The workforce too has to undergo training at the manufacturing company, and have to follow set procedures for most repair jobs. Thus, there is very little scope for innovation at dealer stage, and therefore the priority vector (0.0615) indicates a very low impact of innovation on NPD-SCM alignment.

7.4.2.6 NPD-SCM alignment

The case organization is positioned at the end of the automotive supply chain. The company itself is not much involved in NPD activities but serves as an important channel through which voice of customer is communicated upstream the supply chain to automobile manufacturer and component suppliers, where it provides useful information for NPD activities. As the case company is an authorized outlet of the manufacturer, its competitive advantage is linked to a large extent with the competitiveness of the manufacturer. For instance, a dealer would be able to sell more vehicles if these are considered attractive by the customer on one or more competitive priorities of cost, quality, delivery, variety, or innovation. Similarly, better after sales service and repairs can yield competitive advantage only if the basic product is of good quality. Therefore, since NPD-SCM alignment has a high impact on competitive advantage of the manufacturer, its influence on competitiveness of the case firm is also quite high (0.1839).

7.5 Large-scale survey

Results of the large-scale questionnaire survey give priority vectors for all the five key linkages influencing NPD-SCM alignment, as well as the priority vectors for various factors affecting competitive advantage. The priority vectors drawn from the limit super-matrix for NPD-SCM alignment indicate that influence of linkages such as supply chain responsiveness (0.2762) and voice of customer (0.2409) is very high; that of early supplier involvement (0.2103) and modularity (0.2023) is high; while the priority vector of postponement is very low (0.0703), which indicates that NPD-SCM alignment is not much affected by postponement. Table 7.10 summarizes findings of the survey in form of degree of importance of all the key linkages in influencing NPD-SCM alignment. Since the data inputted for calculating the limit super-matrix contains mean values across all responses, the resulting priority vectors are representative of the entire Indian automotive industry.

TABLE 7.10: Influence of linkages on NPD-SCM alignment – findings of survey

Linkages	Priority vector	Degree of importance
Early supplier involvement	0.2103	High
Voice of customer	0.2409	Very high
Modularity	0.2023	High
Postponement	0.0703	Very low
Supply chain responsiveness	0.2762	Very high

Similarly Table 7.11 exhibits findings related to competitive advantage in Indian automotive industry. It indicates that competitive advantage is influenced most by NPD-SCM alignment

(0.1969), delivery (0.1840), and cost (0.1732). Flexibility (0.1666) and innovation (0.1611) have a moderate influence, while the impact of quality came out to be low (0.1182).

TABLE 7.11: Influence of factors on competitive advantage – findings of survey

Factors	Priority vector	Degree of importance
Cost	0.1732	High
Quality	0.1182	Low
Delivery	0.1840	High
Flexibility	0.1666	High
Innovation	0.1611	High
NPD-SCM alignment	0.1969	High

7.6 Summary of results

Findings of all the three case studies and the large-scale survey, which is representative of the entire Indian automotive supply chain, have been summarized in Table 7.12 and Table 7.13 for easy comparison and discussion. Table 7.12 indicates the influence of various linkages on NPD-SCM alignment in terms of priority vectors and their significance, and Table 7.13 compares the influence of various competitive priorities on competitive advantage.

TABLE 7.12: Comparison of findings – NPD-SCM alignment

NPD-SCM alignment	Survey	Case Study 1 (Supplier)	Case Study 2 (Manufacturer)	Case Study 3 (Dealer)
Early Supply Involvement	0.2103 (high)	0.1943 (moderate)	0.2403 (very high)	0.2219 (high)
Voice of Customer	0.2409 (very high)	0.2467 (very high)	0.2403 (very high)	0.2308 (high)
Modularity	0.2023 (high)	0.2189 (high)	0.2403 (very high)	0.2219 (high)
Postponement	0.0703 (very low)	0.1340 (low)	0.0385 (very low)	0.2031 (high)
Supply chain responsiveness	0.2762 (very high)	0.2062 (high)	0.2403 (very high)	0.1224 (low)

TABLE 7.13: Comparison of findings – Competitive advantage

Competitive Advantage	Survey	Case Study 1 (Supplier)	Case Study 2 (Manufacturer)	Case Study 3 (Dealer)
Cost	0.1732 (high)	0.1716 (high)	0.1737 (high)	0.1994 (high)
Quality	0.1182 (low)	0.1019 (low)	0.1746 (high)	0.2325 (very high)
Delivery	0.1840 (high)	0.1895 (high)	0.1385 (moderate)	0.2105 (very high)
Flexibility	0.1666 (high)	0.1640 (high)	0.1273 (low)	0.1121 (low)
Innovation	0.1611 (high)	0.1443 (moderate)	0.2079 (very high)	0.0615 (very low)
NPD-SCM Alignment	0.1969 (high)	0.2286 (very high)	0.1778 (high)	0.1839 (high)

The variation in impact of each linkage and competitive priority across different stages of the Indian automotive supply chain are discussed below with the objective of validating the findings and generalizing the outcomes.

7.6.1 Linkages influencing NPD-SCM alignment

The influence of various linkages on NPD-SCM alignment varies with the stage at which the company is positioned in the automotive supply chain. The variations in impact of each linkage are discussed below.

7.6.1.1 Early supplier involvement

Findings of the large scale survey indicate a high impact of early supplier involvement on NPD-SCM alignment. Case studies show that the influence of early supplier involvement on NPD-SCM alignment is moderate at supplier stage, very high at manufacturer stage, and high at dealer stage. This is mainly due to the fact that NPD activities are mostly carried out at manufacturer stage of the automotive supply chain, and suppliers need to be involved in order to make the design feasible. The supplier generally procures raw material or basic components from tier 2 or tier 3 suppliers, whose involvement is only moderate. Dealer has to take approval from the manufacturer for all major changes and so impact of early supplier involvement is high. The case studies validate the findings of the large scale survey, and it can be generalized that the influence of early supplier involvement on NPD-SCM alignment is generally high.

7.6.1.2 Voice of customer

Results of survey indicate a high impact of voice of customer on NPD-SCM alignment. All the three case studies report a very high influence of voice of customer and thus support the results of survey. Customer preferences are very important in any NPD activity and serve as a focal point for NPD-SCM alignment. It can be easily generalized that voice of customer is an important linkage for NPD-SCM alignment.

7.6.1.3 Modularity

Results of survey indicate that modularity has a high influence on NPD-SCM alignment. It is validated by the case studies at supplier and dealer stages. The manufacturing stage experiences an even higher impact of modularity, as a large number of components that constitute an automobile increase the scope of forming modules, which can be interchanged to offer more variety to customers. It can be inferred that modularity generally has a high impact on NPD-SCM alignment.

7.6.1.4 Postponement

Survey results show that postponement has a very low impact on NPD-SCM alignment. Supplier also experiences a limited influence of postponement because most of the orders are received well in advance. Manufacturer has an even lesser impact due to the fact that its operations and

NPD activities are not much affected by timing of customer order. However, findings of case study 3 indicate that postponement has a high influence on NPD-SCM alignment in case of a dealer because most of its activities start after receiving customer order. The reasons validate the findings, but the results cannot be generalized for all the stages of the Indian automotive supply chain. It can be concluded that postponement has little influence on in case of supplier and manufacturer, but it is a strong linkage for improving NPD-SCM alignment in case of a dealer and after sales service provider.

7.6.1.5 Supply chain responsiveness

The survey results exhibit that the influence of supply chain responsiveness on NPD-SCM alignment is very high. It is supported by supplier and manufacturer, but not by dealer in which case the impact comes out to be low. Again the underlying factor of variation is the fact that dealer is having limited NPD activities and thus requires little responsiveness from the supply chain. The findings are valid and can be explained through the reasons discussed for each supply chain stage. However, they cannot be generalized for the entire supply chain. Supply chain responsiveness is important for supplier and manufacturer, but not at the dealer stage.

7.6.2 Competitive priorities

The significance of competitive priorities varies with the stage of the supply chain. A brief discussion of the competitive priorities is presented below.

7.6.2.1 Cost

Cost is an important factor which has a high influence on competitive advantage across all stages of the Indian automotive supply chain. This has universally been established through the findings of the survey across different industries of the Indian automotive supply chain, as well as through each of the case studies. The findings are clearly validated and it can be generalized that cost is an important competitive priority in Indian automotive industry, and has a high impact on competitive advantage.

7.6.2.2 Quality

Findings of survey indicate a low influence of quality on competitive advantage. This is primarily due to the fact that within a price segment, quality has become an 'order qualifier'. However, the empirical findings are supported only by the case study of supplier, who has little control over varying quality level which has been fixed by the manufacturer. The manufacturer and dealer stages consider quality as a high competitive priority, mainly due to their proximity to the customer. The results of survey cannot be generalized for all the three stages.

7.6.2.3 Delivery

Results of the empirical study suggest delivery as an important competitive priority. This has been validated by findings of case studies at supplier stage whose customers are powerful multi-national automakers, as well as dealer stage, whose customers may drift to rivals if delivery is not dependable. However, manufacturer considers delivery as a basic requirement, which has a moderate influence in improving competitive advantage. The results are again valid but cannot be generalized.

7.6.2.4 Flexibility

The empirical survey across all stages of Indian automotive supply chain indicates a high influence of flexibility on competitive advantage, which is supported only by the supplier case study. In case of manufacturer and dealer, the influence of flexibility on competitiveness comes out to be low. There is a mismatch between findings of the survey and the case studies. Perhaps the survey questionnaire could not capture the influence of flexibility properly. In such situation, the results of the survey cannot be generalized.

7.6.2.5 Innovation

The effect of innovation across all the stages of automobile supply chain as captured by the survey comes out to be high. This is supported by the case study at manufacturer stage where innovation is considered as an extremely important competitive priority. However its impact at supplier stage is only moderate since it has to produce components as specified by the manufacturer. At the dealer stage, influence of innovation is quite low due to the fact there is little NPD activity at the dealer stage. Since the survey uses mean of responses across all the three supply chain stages, the effect of innovation has got averaged over a large number of industries. The findings can be validated by the above reasons, but cannot be generalized for all the three supply chain stages.

7.6.2.6 NPD-SCM alignment

The findings of the large-scale survey of Indian automobile companies indicate that influence of NPD-SCM alignment in improving competitive advantage is high. All the three case studies also suggest high influence of NPD-SCM alignment as a competitive priority. In fact, in case of the supplier, the impact of NPD-SCM is perceived to be very high because most NPD activities are performed in collaboration with supply chain partners. For manufacturer, the existence of large number of supply chain partners necessitates a high alignment of supply chain partners in NPD efforts. Whatever limited NPD activity is there at the dealer stage has to be performed in consultation with the manufacturer. Thus the findings are valid and can be generalized for all the three stages of the supply chain.

Therefore, there is clear evidence that NPD-SCM alignment has a high impact on competitive advantage across the entire Indian automotive industry.

7.7 Contribution made by the research

There is growing evidence in recent literature of linkages between new product development and supply chain management activities. Over the years, both the activities have been individually used by industry to gain competitive advantage. The current research shows that a company's performance and hence competitive advantage can be improved as a result of coordination between NPD and SCM activities. The functional areas where the linkages are strong have some visible benefits of the coordination. On the basis of the results discussed above, following outcomes can be drawn from the research:

1. There is sufficient evidence of NPD-SCM alignment in Indian automobile industry, particularly in the passenger car segment, which is witnessing a high competition amongst global giants.
2. Five key linkages have been identified through literature review and experts' opinion that have significant influence on NPD-SCM alignment in Indian automobile industry.
3. An integrated framework has been developed to capture the influence of key linkages in improving NPD-SCM alignment, and its resulting impact on competitive advantage in comparison to other established competitive priorities.
4. Linkages such as early supplier involvement, voice of customer, modularity and supply chain responsiveness have a high impact on NPD-SCM alignment. Postponement is not much significant, as there is no mass customization in Indian automobile industry till date; however it becomes important towards the customer end of the supply chain.

5. NPD-SCM alignment positively influences competitiveness of Indian automobile industry. In some cases, its impact on competitive advantage is more than some of the established competitive priorities such as cost, quality, delivery, flexibility and innovation. Its influence is more visible towards the supplier end of the Indian automobile supply chain.

In different times, companies have adopted various strategies to gain competitive advantage over their rivals. In early days, cost used to be the most important factor, and then it was quality in 1970s and 1980s, followed by delivery (customer satisfaction) and flexibility in 1990s, and innovation in first decade of the 21st century. With all these factors almost reaching saturation, NPD-SCM alignment can be perceived as a new strategy to gain competitive advantage, especially in industries where new product development and supply chain management activities are important, such as the automobile sector.

7.8 Limitations of the research

Although this research has made significant contributions from both theoretical and practical point of views, it also has some limitations, which are described below. The perusal of these limitations shall assist future researchers to overcome them.

In this research, respondents in form of individuals working at different job functions (NPD, purchasing, operations, materials, and logistics) in an organization were asked to respond to all the issues related to NPD as well as SCM. However, no person in an organization is in a position to answer all the questions: for example, procurement professionals are mainly responsible for purchasing and supply side, and thus may be not in an appropriate position to respond to customer-related questions; the main area of operations managers is production / operations and they may not have sufficient knowledge of their suppliers and customers.

Therefore, the use of single respondent may affect the accuracy of measurement.

The response rate of 11.33%, although comparable to similar studies, is a bit low. Future research questionnaires may be directed either through the top management in order to ensure higher response rates, or help of some professional bodies / research organizations may be sought to get more responses.

The study is limited to Indian automobile industry, which limits the generalizability of its findings to other industry types. Future researchers can conduct / extend the study to other types of industries for generalizing the outcomes.

7.9 Directions for future research

Some new areas of opportunities have emerged over the last decade, particularly as a result of globalization (including company merger and acquisition) and advancement in information technology, which have not been fully explored yet. Some of them are mentioned below as recommendations for future research.

7.9.1 Customer linkage analysis and optimization

Literature review shows that prior works have been more concentrated on the supplier linkage than the customer linkages. Supplier linkages or interactions include studies focusing on early supplier involvement, design for supply chain, 3-dimension concurrent engineering, platform commonality, and modularity. On the other hand, interaction with customers, at least in the prior literature, is limited to concepts such as voice of customer, postponement, and customer relationship management. More linkages need to be explored at the customer end, because it is ultimately customer satisfaction that holds the key to success of any business organization. To this end, few areas of opportunity for further research include joint demand planning, linking commonality in design with sales and marketing, and designing product lifecycle based customer support systems.

7.9.2 Model scope and measurement techniques

The scope of existing models is generally confined to strategic level of decision making with a limited set of decision variables. Details of operational level planning may also be included for making the model effective for operations managers. On the other hand, as the number of linkages and the details of operational level increase in a single comprehensive model, complexity of the problem is bound to increase significantly. Therefore, study on evaluating the need of complex models and the trade-off associated with the benefits versus complexity would be an interesting value addition to current NPD-SCM alignment framework.

Furthermore, the types of measuring instruments used in prior research to measure the level of each linkage and its effect on performance vary significantly across the researchers. Most researchers have used soft scales such as five point Likert scale or nine point Saaty scale, but there is hardly any standardization of survey instruments. The fact that the same linkage has been measured using different instruments decreases reliability and makes the measurement questionable. Standardization of measuring instruments and development of some hard scales which could provide more accurate values of various linkages is another major gap and needs to be bridged by further research.

7.9.3 Balance of power among supply chain partners

It has been observed that little attention has been given to the role of other factors such as business conditions and balance of power in a supply network in measuring the effect of this interaction. The relationship between product development and supply chain management activities is seldom equally influenced by both. It generally has a bias with one of the two having a more powerful influence on the relationship. Generally it is assumed that the customer holds the balance of power in the buyer-supplier relationship, with suppliers having to conform to the requirements of the customer (Bates and Slack 1998). However, during new product development, suppliers can be an important source of innovation, and thus may sometimes become powerful (Smals and Smits, 2012). In cases where the suppliers are considerably stronger than their customers, they might exert their power to influence a product development project for their own benefits (Zolghadri et al., 2011). Existence of a strong power bias towards either customers or suppliers negatively influences knowledge sharing among supply chain partners and thus performance of new product development (He et al., 2012). In such situation, smaller companies should try to maintain power balance through application of their proprietary and or specialist knowledge that is core to their business (Bates and Slack, 1998). In any case, there should be a clear understanding of power distribution between the focal firm and its supply chain partners. Almost all the existing models and frameworks developed for measuring the effect of linkages on performance have overlooked the problem of power bias. This is a clear gap and offers a rich potential for further investigation.

7.9.4 Impact of technology turbulence and business uncertainties

Factors such as technology turbulence and uncertainty in business environment may also act as obstacles during integration of new product development and supply chain management activities, and in some cases, may even increase the risk of failure (Porter, 1985; Childerhouse et al., 2002). This may further be aggravated by organizational inertia, cultural diversity and geographical complexity in the supply chain. Such factors influence the type and the optimal level of integration, and therefore must be considered as limitations while aligning product development and supply chain management activities.

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APPENDIX - A

INITIAL POOL OF CONSTRUCTS FOR MEASURING RESEARCH VARIABLES

1. Early supplier involvement

1	Our firms forecasts are coordinated with our suppliers
2	We include our key suppliers in our planning and goal- setting activities
3	We inform our suppliers in advance of changing needs
4	We actively involve our key suppliers in new product development processes
5	Our manufacturing capabilities are formally communicated with key suppliers
6	Our suppliers share knowledge of core business processes related to us
7	We have continuous improvement programs that include our key suppliers
8	We regularly solve problems jointly with our suppliers
9	We have helped our suppliers to improve their product quality
10	Our suppliers keep us fully informed about issues that affect our business
11	Our firm's formal performance goals are communicated to our suppliers

2. Voice of customer

1	We frequently take feedback from our customers
2	We frequently measure and evaluate customer satisfaction
3	We frequently determine future customer expectations
4	We facilitate customers' ability to seek assistance from us
5	We periodically evaluate the importance of our relationship with our customers
6	We inform our customers in advance of making changes in our product design, mix or volume
7	Our firms forecasts are coordinated with our customers
8	Our customers keep us fully informed about issues that affect our business
9	Our customers share knowledge of their core business processes related to us
10	Our manufacturing capabilities are formally communicated with key customers
11	We involve key customers in our new product development process
12	Our firm's formal performance goals are communicated to our customers
13	We regularly solve problems jointly with our customers

3. Modularity

1	Our products share common modules
2	Product modules can be re-assembled into different forms
3	Product feature modules can be added to a standard base unit
4	Our production process is designed as adjustable modules
5	Our production process can be adjusted by adding new process modules
6	Production process modules can be adjusted for changing production needs
7	Production teams can be re-assigned to different production tasks
8	Production team members can be re-assigned to different teams

4. Postponement

1	We delay production until customer orders have actually been received
2	We delay final product assembly activities until customer orders have actually been received
3	We delay final product assembly activities until the last possible position (or nearest to customers) in the supply chain
4	We delay ordering of supplies from suppliers until customer orders have actually been received
5	We delay some form of value-addition to the product until customer orders have actually been received
6	Production process modules can be rearranged so that customization sub-processes occur last
7	Postponement opportunities are evaluated jointly with key customers
8	Postponement opportunities are evaluated jointly with key suppliers

5. Supply chain responsiveness

1	Our operations system responds rapidly to changes in product volume demanded by customers
2	Our operations system responds rapidly to changes in product mix demanded by customers
3	Our operations system effectively expedites emergency customer orders
4	Our operations system rapidly reconfigures equipment to address demand changes
5	Our operations system rapidly reallocates people to address demand changes
6	Our operations system rapidly adjusts capacity to address demand changes
7	Our logistics system responds rapidly to changes in product volume
8	Our logistics system responds rapidly to changes in product mix
9	Our logistics system responds rapidly to unexpected demand change
10	Our major suppliers are able to accommodate our request for change product volume in a relatively short time
11	Our major suppliers are able to accommodate our request for change product mix in a relatively short time
12	Our major suppliers effectively expedite our emergency orders
13	Our firm can customize products on a large scale

6. NPD – SCM alignment

1	Our new product development goals are framed in consultation with our supply chain partners
2	Our firm's key suppliers understand how their decisions / actions affect our NPD process
3	Our firm's key customers understand how their decisions / actions affect our NPD process
4	Our firm has an extensive understanding of our supply chain's constraints / capabilities as they relate to our product development activities
5	Our firm has formal guidelines concerning supplier and / or customer involvement in our NPD process
6	Our new product development process involves our key suppliers
7	Our new product development process involves our key customers
8	Our firm and its key suppliers share the NPD information freely
9	Our firm and its key customers share the NPD information freely
10	We and our suppliers have clearly defined responsibilities in product development
11	We and our customers have clearly defined responsibilities in product development
12	Our firm and its key suppliers share the costs of developing products
13	Our firm and its key suppliers share the benefits of new product introduction
14	Our firm and its key customers share the costs of developing products
15	Our firm and its key customers share the benefits of new product introduction
16	Our new product development process is in alignment with the capabilities and limitations of our supply chain

7. **Competitive advantage**

	As compared to our major competitors -
1	We are able to offer prices as low or lower than our competitors
2	We offer high quality products to our customers
3	We offer products that are highly reliable
4	We offer products that are very durable
5	We deliver customer orders on time
6	We alter our product offerings to meet client needs
7	We cater to customer needs for “new” features
8	We have time-to-market lower than industry average
9	We have fast product development

APPENDIX - B

SURVEY QUESTIONNAIRE

A SURVEY OF NPD-SCM ALIGNMENT AND ITS EFFECT ON COMPETITIVE ADVANTAGE IN INDIAN AUTOMOTIVE INDUSTRY

General Instructions and Information

• This survey is being conducted by Ankur Pareek, a Ph.D. candidate, under supervision of Prof. A.P.S. Rathore (Head, Dept. of Management Studies) and Prof. Rakesh Jain (Head, Dept. of Mechanical Engineering), Malaviya National Institute of Technology, Jaipur, Rajasthan, India.

• This research aims to study the effect of alignment between new product development and supply chain management activities on competitive advantage in Indian automotive industry. The objective is to determine the current level of NPD–SCM alignment, some prominent linkages influencing the alignment, and the effect of this alignment on competitive advantage of the firm.

• It should normally take 15-20 minutes to complete the survey.

• **All responses will be kept confidential. Data will be used for academic purpose only.**

• If you would like to get a copy of the executive summary of results, please provide your e-mail id on the last page of this survey.

• In case of any queries, please contact:

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QUESTIONNAIRE

Please indicate the response to each question by choosing the option which describes the correct / closest answer in your opinion. There is no right or wrong answer. Please provide **your best estimate.**

Linkages

From literature review, some linkages between new product development (NPD) and supply chain management (SCM) activities have been observed.
The following questions aim to find out the level of these linkages in your organization.

1. Early supplier involvement (ESI)

Early supplier involvement is the practice of involving key suppliers early in the planning and or product development phase, or while making strategic or major decisions.

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	We include our key suppliers in our planning and goal-setting activities					
2	Our firm's forecasts are coordinated with our suppliers					
3	We and our suppliers share knowledge of core business processes related to each other					
4	We regularly solve problems jointly with our suppliers					
5	We actively involve our key suppliers in new product development processes					

2. Voice of customer (VOC)

Voice of customer is the feedback of customers regarding their preferences about product design features, quality and other attributes.

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	We frequently take feedback from our customers					
2	We frequently determine future customer expectations					
3	We include our key customers in our planning and goal-setting activities					
4	We and our customers share knowledge of core business processes related to each other					
5	We actively involve our key customers in new product development processes					

3. Modularity

Modularity is the practice of using standardized product modules which can be easily re-assembled / re-configured into different functional forms (product modularity), and / or standardizing manufacturing process into modules which can be re-sequenced / re-arranged easily in response to changing product requirements (process modularity).

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	Our products share common modules					
2	Product modules can be reassembled into different forms					
3	Product feature modules can be added to a standard base unit					
4	Our production process is designed as adjustable modules					
5	Production process modules can be re-sequenced for changing production needs					
6	Our production process can be adjusted by adding new process modules					

4. Postponement

Postponement is the practice of moving forward one or more operations or activities (producing, sourcing, and delivering) to a much later point in the supply chain.

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	We delay production until customer orders have actually been received					
2	We delay final product assembly activities until the last possible position (or nearest to customers) in the supply chain					
3	We delay ordering of supplies from suppliers until customer orders have actually been received					
4	We delay some form of value addition to the product until customer orders have actually been received					
5	Production process modules can be rearranged so that customization sub-processes occur last					

5. Supply chain responsiveness

Supply Chain Responsiveness is the promptness and the degree to which the supply chain can address changes in customer demand, through operations (manufacturing) system responsiveness, logistics process responsiveness, and supplier network responsiveness.

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	Our operations / manufacturing system can adjust to changes in product mix / volume demanded by customers					
2	Our operations system rapidly reallocates people to address demand changes					
3	Our operations system effectively expedites emergency customer orders					
4	Our logistics system responds rapidly to unexpected demand change in product mix / volume					
5	Our major suppliers are able to accommodate our request for change in product mix / volume in a relatively short time					

NPD – SCM alignment

NPD-SCM alignment is the degree to which new product development and supply chain management activities are carried out in a coordinated manner. Alignment can be achieved by considering the capabilities and limitations of a firm's supply chain while designing a product, and in some cases, simultaneous design of product, process and its supply chain.

6. Measuring NPD-SCM alignment

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	Our firm has an extensive understanding of our supply chain's constraints / capabilities as they relate to our product development activities					
2	Our new product development goals are framed in consultation with our supply chain partners					
3	Our new product development process involves our key supply chain partners					
4	We and our supply chain partners have clearly defined responsibilities in new product development					
5	Our firm and its key supply chain partners share the costs and benefits of developing new products					

7. Contribution of linkages in improving NPD-SCM alignment

Please indicate the influence of the following practices in improving the alignment / coordination between NPD and SCM activities of your firm. Please rate the influence on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Early supplier involvement									
2	Voice of customer									
3	Modularity									
4	Postponement									
5	Supply chain responsiveness									

Inter-dependencies among linkages with respect to influencing NPD-SCM alignment

Inter-dependencies may exist among the factors that influence a criterion. For example, modularity and early supplier involvement are two of the five factors that influence NPD-SCM alignment (criterion) directly; at the same time, they may also affect each other, e.g. modularity may affect early supplier involvement, which in turn influences NPD-SCM alignment. Thus, modularity may influence NPD-SCM alignment directly, as well as indirectly through early supplier involvement. Similarly, early supplier involvement may also be influenced by some of the remaining factors such as voice of customer, postponement, etc.

8. When influencing NPD-SCM alignment of your firm, please indicate the degree to which *early supplier involvement* is influenced by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Voice of customer									
2	Modularity									
3	Postponement									
4	Supply chain responsiveness									

9. When influencing NPD-SCM alignment of your firm, please indicate the degree to which *voice of customer* is influenced by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Early supplier involvement									
2	Modularity									
3	Postponement									
4	Supply chain responsiveness									

10. When influencing NPD-SCM alignment of your firm, please indicate the degree to which *modularity* is influenced by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Early supplier involvement									
2	Voice of customer									
3	Postponement									
4	Supply chain responsiveness									

11. When influencing NPD-SCM alignment of your firm, please indicate the degree to which *postponement* is influenced by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Early supplier involvement									
2	Voice of customer									
3	Modularity									
4	Supply chain responsiveness									

12. When influencing NPD-SCM alignment of your firm, please indicate the degree to which *supply chain responsiveness* is influenced by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Early supplier involvement									
2	Voice of customer									
3	Modularity									
4	Postponement									

Competitive advantage

Competitive Advantage is defined as the capability of an organization to create an advantageous position over its competitors.

13. Measuring Competitive advantage

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
1	We are able to offer prices as low or lower than our competitors					
2	We offer high quality products to our customers					
3	We deliver customer orders on time					
4	We alter our product offerings to meet client needs					
5	We cater to customer needs for “new” features					

14. NPD-SCM alignment improves competitive advantage

Please select the most appropriate answer.

Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent
1	2	3	4	5

		1	2	3	4	5
	Alignment between NPD and SCM activities has improved competitive advantage of our firm					

15. Contribution of linkages in improving competitive advantage

Please indicate the influence of the following practices in improving the competitive advantage of your firm.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Cost									
2	Quality									
3	Delivery									
4	Flexibility									
5	Innovation									
6	NPD-SCM alignment									

Interdependencies among factors with respect to influencing competitive advantage

Interdependencies may exist among the factors that influence competitive advantage. For example, when cost affects competitive advantage, it may itself be influenced by some of the remaining factors such as quality, flexibility, innovation, etc.

16. When influencing competitive advantage of your firm, please indicate the degree to which *cost* is affected by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Quality									
2	Delivery									
3	Flexibility									
4	Innovation									
5	NPD-SCM alignment									

17. When influencing competitive advantage of your firm, please indicate the degree to which *quality* is affected by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Cost									
2	Delivery									
3	Flexibility									
4	Innovation									
5	NPD-SCM alignment									

18. When influencing competitive advantage of your firm, please indicate the degree to which *delivery* is affected by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Cost									
2	Quality									
3	Flexibility									
4	Innovation									
5	NPD-SCM alignment									

19. When influencing competitive advantage of your firm, please indicate the degree to which *flexibility* is affected by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Cost									
2	Quality									
3	Delivery									
4	Innovation									
5	NPD-SCM alignment									

20. When influencing competitive advantage of your firm, please indicate the degree to which *innovation* is affected by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Cost									
2	Quality									
3	Delivery									
4	Flexibility									
5	NPD-SCM alignment									

21. When influencing competitive advantage of your firm, please indicate the degree to which *NPD-SCM alignment* is affected by each of the following.

Please indicate on a scale of 1 to 9, where 1 indicates extremely low and 9 indicates extremely high degree of influence.

		1	2	3	4	5	6	7	8	9
1	Cost									
2	Quality									
3	Delivery									
4	Flexibility									
5	Innovation									

Demographic Information

Following questions are intended to seek some general information about the respondent's experience in Indian automotive supply chain and profile of the organization, with the purpose of assessing the relevance of the response with the topic of this survey.

22. Name of organization ____

23. Geographical location of your organization

a) North India b) South India c) East India d) West India
e) Central India

24. Approx. number of workforce (employees plus contractual labour)

b) 1-50 b) 51-100 c) 101-250 d) 251-500 e) above 500

25. Approx. annual sales (in million USD)

a) Less than 10 b) 10-25 c) 25-50 d) 50-100 e) above 100

26. Position of your firm in the supply chain (mark all that apply)

a) Raw material supplier b) Component supplier c) Manufacturer
d) Sub-assembler e) Assembler f) Distributor
g) Wholesaler h) Retailer i) Other

27. Your firm is a part of which type of automobile supply chain (mark all that apply)

a) Two wheelers b) Passenger cars c) Commercial vehicles d) Other

28. Your company's primary production system is (choose all that apply)

b) Engineer to order b) Make to order c) Assemble to order
d) Make to stock

29. Your company's primary process choice is (choose all that apply)

a) Continuous b) Line c) Batch
d) Job shop e) Project

30. Your present job function (mark all that apply):

a) Production / operations
b) Engineering / product development
c) Procurement
d) Logistics / distributions / sales
e) Marketing/sales/customer relations
f) After sales service
g) Human resource management
h) Corporate executive / senior management
i) Finance
j) Other

31. Your present job position in your organization

a) Top management
b) Senior management
c) Middle management
d) Engineer / Executive
e) Other

32. Your total work experience in this area

a) Upto 5 years
b) 5-10 years
c) 10-15 years
d) 15-20 years
e) more than 20 years

33. Your name (optional)____

34. Would you like to get a copy of the executive summary of results of this survey? Yes / No

If yes, please mention your e-mail id: ____

THANK YOU

LIST OF PUBLICATIONS

1. A. Pareek, R. Jain, A.P.S. Rathore, 2011. Integrating product development and supply chain management. International Conference on Industrial Engineering (ICIE-2011), NIT Surat, India.

2. Ankur Pareek, 2011. Improving productivity through optimum resource utilisation-a case study. 3rd International Conference on Transforming Business Organisations for Longevity – Challenges and Opportunities, Prestige Institute of Management, Gwalior, India.

3. Pareek Ankur,Jain Rakesh and Rathore A.P.S., 2012. Does modularity influence new product development and supply chain management? Abstract accepted in 3rd International Conference on Engineering Project and Productions Management (EPPM) 2012, Brighton, UK.

4. Ankur Pareek, Ajay Rathore, Rakesh Jain, 2013. Modularity as a strategic option for product proliferation in India automotive supply chain. Industrial and Systems Engineering Research Conference (ISERC), Puerto Rico.

5. Ankur Pareek, Ajay Pal Singh Rathore, Rakesh Jain, 2013. Evaluating alignment between new product development and supply chain management in Indian automotive firm using analytic network process. International Conference on Mechanical Engineering and Mechatronics (ICMEM), Toronto, Ontario, Canada.

6. Ankur Pareek, Ajay Pal Singh Rathore, Rakesh Jain, 2013. Linking new product development and supply chain management – evidence from Indian automotive industry. IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) 2013, Bangkok, Thailand.

7. Ankur Pareek, Ajay Pal Singh Rathore, Rakesh Jain, 2013. Aligning new product development and supply chain management – a case study. International Conference on Industrial Technology and Management, ICITM-2013, Darussalam, Brunei.

8. Ankur Pareek, Bimal Nepal, Ajay Pal Singh Rathore, Rakesh Jain, 2013. On linkages between new product development and supply chain management. International Journal of Product Development. [IJPD-57235(under review)]

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Ankur Pareek was born in Jaipur, Rajasthan, India on 27th May 1973. He is currently working as Associate Professor in Department of Mechanical Engineering, Government Engineering College, Ajmer, India. He did his graduation in Mechanical Engineering from M.B.M. Engineering College, Jodhpur, India in 1996 and completed Masters degree in 1999 from Malaviya Regional Engineering College, Jaipur, India with specialization in Manufacturing Systems Engineering. Currently, he is pursuing his Doctoral studies as a part time candidate from Malaviya National Institute of Technology, Jaipur, India. He has been teaching various courses of Mechanical Engineering to undergraduate and post graduate students for the last 15 years. His research interests are focused around multi-disciplinary aspects of operation management, new product development and supply chain management.