# Chapter 1

# Introduction

This chapter provides a brief of the entire research work on 'Study and development of models for supply chain performance measurement in select industries'. The present research examines existing Supply Chain performance measurement frameworks, identifies strengths and gaps in order to develop appropriate models for supply chain performance measurement. Rational use of operations research techniques, heuristics and computer-based simulation techniques have been incorporated with existing highly cited frameworks of performance measurement to develop Supply Chain Performance Measurement models. Performance measurement models are developed in the areas of strategic alignment, supply chain flexibility, sustainability, maintenance planning and network modelling.

## 1.0 INTRODUCTION

Managing Supply Chain (SC) operations is important to any enterprise's capability to compete successfully (S. Li, Ragu-Nathan, Ragu-Nathan, & Subba Rao, 2006). Good Supply Chain Management (SCM) approaches facilitates in a variety of benefits such as increased profitability, improved customer value, lower cycle times and reduced inventory levels (Christensen, Germain, & Birou, 2007; Fawcett, Magnan, & McCarter, 2008; S. Li et al., 2006). Supply Chains are becoming economic engines to create value and provide maximum benefit to its members (A Lockamy & McCormack, 2004). In a dynamic and competitive environment, business enterprises now realises that understanding, monitoring and controlling their performance is vital (Maestrini, Luzzini, Maccarrone, & Caniato, 2017). Recent studies indicate that Performance Measurement has been recognised as a vital component to advance and sustain businesses (Maestrini et al., 2017; Taticchi, Tonelli, & Cagnazzo, 2010). Review of related literature indicates that more organisations are focussing on SC wide performance measures in the past two decades. Therefore, organisations now appreciates that focussing on performance measurement of the entire SC is an emergent necessity (Charan, Shankar, & Baisya, 2008).

Various performance metrics are developed since last two decades for measuring multiple attributes of SC. The multiple approaches to SC performance measures include

financial and non-financial perspective; strategic, tactical and operational approach (Gunasekaran, Patel, & Tirtiroglu, 2001); business process approach and financial approach (Beamon, 1999b). While evaluating measurement models, it is noticed that many models only have a theoretical support, while some of the measurement models have the backing of empirical testing (Taticchi et al., 2010). Literature survey on Supply Chain Performance Measurement Systems (SCPMS) indicates that there are gaps still existing and significant amount of research is necessary to develop and implement appropriate performance measurement models. Significance and necessity of performance measurement of SC is adequately established in the literature and thus encourages research in this area.

The aim of the present research is to present the study and models for Supply Chain Performance Measurement (SCPM). The present research examines existing performance measurement frameworks in SCs, identifies strengths and gaps to develop appropriate models for SCPM. The comparative study of common frameworks and models for performance measurement helped to identify research gaps and focus of research agenda. Rational use of operations research techniques, heuristics and computer-based simulation techniques have been incorporated with existing highly cited frameworks of performance measurement.

The objectives of this chapter are: (a) to bring out the broad changes in the SCPM landscape that form the motivation for this thesis and, (b) to provide a brief agenda for the thesis based on that motivation.

## 1.1 Supply Chain Management

*"Management is on the verge of a breakthrough in understanding how industrial company success depends on the interactions between the flows of information, materials, money, manpower, and capital equipment. The way these five flow systems interlock to amplify one another and to cause change and fluctuation will form the basis for anticipating the effects of decisions, policies, organizational forms, and investment choices."* Forrester (1958). Around six decades ago, Forrester identified importance of managing flows across business entities and forecasted the advent of today's SC management. The terms supply chain management and supply chain appear to have been first used in the year 1982 to include activities that relate to "movement and storage of raw-material, work-in-process goods and finished inventory from their points of origin to destination" (Laseter & Oliver, 2003).

The second half of the 20th century, especially the past three decades, saw a proliferation of multinational corporations (MNCs); although MNCs did exist before that and their history goes back as far as the East India Company founded in 1600 (Pandey, 1994). Initially in countries such as India, due to several factors such as uncertain political environment, MNCs primarily indulged in partnerships with local companies and restricted their own presence and operations. Thus, the primary currency of transaction for them was knowledge as seen in technology transfer arrangements in the cases of TVS Motors and Suzuki, Hero Motors and Honda, defence production and Nissan and so on. As globalisation increased in depth and spread, and wherever political environments became more and more conducive, MNCs started to establish subsidiaries as seen in the case of India where about 4000 MNCs have their presence today ("List of MNCs in India," 2016; *World investment report*, 2009; *World investment report*, 2016). With this increased globalisation of business environments, an associated phenomenon emerged: outsourcing increasingly moved off-shore. Increasingly, enterprises found it easier and profitable to outsource part or whole of the value creation process to outside their countries. What began as a problem of integrating departments now became a problem of integrating companies across national boundaries. Integration between companies fundamentally involves movement of material, finance and information. Companies such as Calvin Klein and Nike produce their goods and source raw materials from several countries such as India, Sri Lanka and Bangladesh and sell their products in the different countries. Supply Chain management implicitly or explicitly became a much larger concern than ever before.

The focus on SC management research has been on the customer side or supplier side of the SC (S. Li et al., 2006). On the supplier side, issues like as supplier selection, supplier participation and production performance, the impact of supplier coalitions, effect of associations with suppliers in refining supplier responsiveness etc. are researched extensively (Balfaqih, Nopiah, Saibani, & Al-Nory, 2016; S. Li et al., 2006). There are many research work available in literature on the customer side of a SC, though these are lesser in numbers than the research works available in the supplier side of the SC (S. Li et al., 2006). The downstream linkage between manufactures, distributors and retailers were studied by many researchers (Alvarado & Kotzab, 2001; Nyaga, Whipple, & Lynch, 2010; Yu, Jacobs, Salisbury, & Enns, 2013; Zhao, Huo, Flynn, & Yeung, 2008). There are many very less number of researchers who have studied the complete upstream and downstream aspects of the SC in an integrated manner (S. Li et al., 2006; Tan, 2002). Another recent focus on SCM research has been

sustainability and greening of supply chain (Taticchi, Tonelli, & Pasqualino, 2013; Walker, Seuring, Sarkis, & Klassen, 2014).

SCM considers the product life cycle management from cradle to cradle (C2C), i.e., from inventory acquisition (supply) to manufacturing (production), delivery, consumer service and finally the recycling, return, repair or disposal of the item. Many companies now realise that the only areas left for cost reduction is in the area of SC costs (Morgan, 2007). Therefore, researchers argue that the competition is now between the supply chains and not between companies (Lambert & Cooper, 2000) though others disagree (Rice & Hoppe, 2001). The trends of globalisation, business benefits of outsourcing and the advances in information technology reduced the boundaries of organisations and necessitated integration (Balfaqih et al., 2016). However, a key element of SCM which has been comparatively ignored is the area of SCPMS (Cagnazzo, Taticchi, & Brun, 2010; Gunasekaran & Kobu, 2007). To achieve organisational goals, companies depend on their SC's Performance Measurement Systems (PMS). PMS helps organisation to align their strategy with their resources and processes.

### 1.2 Supply Chain Performance Measurement

Performance measurement can be an effective tool available to managers to monitor, manage and enhance systems capabilities and performance. PMS for the entire SC is necessary to manage a SC effectively and retain the competitive advantage. Kaplan and Norton stated in 1992 that, *'if there is no measures, there is no improvement'* (Kaplan & Norton, 1992). Measurement criteria depending on organisational goals facilitate timely, appropriate decision making (Balfaqih et al., 2016). Literature mentions different purposes for developing a SCPMS (Balfaqih et al., 2016; Cagnazzo et al., 2010; Gunasekaran & Kobu, 2007) and these are:

1. Identify success (success factors, KPIs)
2. Identify customer needs and measure customer satisfaction
3. Understand, monitor and improve business processes
4. Help in factual and timely decisions
5. Track and enable progress
6. Identify bottlenecks and improvement opportunities
7. Waste reduction (operational and material)

Supply chain performance is a widely-researched topic but highly fragmented. Literature review reveals that very less number of studies concentrates on the performance of SCs as an

entirety. Instead many researchers focussed on key processes or some parts of the SC. Due to the wide variety of SCs that can be seen in industries, a variety of performance measures has been suggested such as cost, speed, flexibility, competitive advantage and so on. However, a search for a unified concept that can encompass all such measures yielded one satisfactory construct: *SC surplus* (Chopra & Meindl, 2013). It is the difference between the customer value that a SC creates and the cost it incurs in doing so. An alternative definition replaces customer value with profit but it fails to differentiate between customer value (which is the price a customer is ready to compensate for the product) and actual price set by the SC. Due to its elegance in unifying both the value related elements and the cost related elements in a simple manner, SC surplus becomes an ideal construct for quantifying the performance improvement of an SC. Gunasekaran & Kobu, (2007) classified SCPMS literature on the basis of different criterion.

They are:

1. "Balanced scorecard (BSC) perspective (financial, customer, internal business process and learning and growth)"
2. "Components of performance measures (resource, output and flexibility)"
3. "Location of measures in SC links (plan, source, make and deliver)"
4. "Decision-making levels (strategic, tactical and operational)"
5. "Nature of measures (financial and non-financial)"
6. "Measurement base (quantitative and non-quantitative)"
7. "Traditional vs. modern measures (function-based or value-based)"

Another classification of SCPMSs is based on methods implemented for development and assessment purposes. Analytical Hierarchy Process (AHP), Analytic Network Process (ANP), Delphi/Survey, Simulation, Data Envelopment Analysis (DEA) and Uncertainty theory are the most widely used techniques for SCPMS (Balfaqih et al., 2016). An outline of the diverse performance metrics and measures within SCs is described at Chapter 2 of this thesis titled 'Literature Review'.

### 1.3 Research Questions

Based on literature survey and expert opinion, a set of research questions are identified and formulated to provide a direction to the research. These questions are the following:

**RQ 1:** What are the strengths and limitations of the existing frameworks of SCPMS?

**RQ 2:** Can the existing SC Performance Measurement Frameworks be improved? If so, how to improve existing SCPM Frameworks?

**RQ 3:** What are SCPM needs and expectations of select Indian Industry? How are these needs met in the existing setup?

**RQ 4:** What technology is available for SCPM? What are the Operations Research (OR), Heuristic, Modelling and other techniques suitable for incorporation with SCPMS?

**RQ 5:** Can OR, Heuristic, Modelling and other techniques be integrated with SCPMS framework? What are the benefits of integrating these techniques with SCPMS?

**RQ 6:** How to analyse the effectiveness and suitability of a SCPM framework for a select SC?

**RQ 7:** What lessons can be learned on implementation of integrated SCPM framework?

## 1.4 Research Objectives

Extensive study of relevant literature has been carried out to derive at the appropriate research questions and research objectives. Specifying the research objectives helped to focus the research and guide the study. The list of research objectives is mentioned in the succeeding paragraphs:

### 1.4.1 Identify strengths, limitations and opportunity for improvement of existing frameworks of SCPMS

The past two decades witnessed development of many models and frameworks for SCPMS. There are many positives and negatives associated with these PMSs (Bititci, Turner, & Begemann, 2000). Literature review indicates that empirical and theoretical validity of some of the frameworks are established whereas information about others are not available. Some of the most widely cited measurement systems are analysed to understand their strengths and limitations. A comparison based on literature survey on the strengths and limitations of existing PMS has been done and is given at Chapter 2, Literature Survey.

### 1.4.2 Identify SCPM practices of Indian industry

Saad & Patel, (2006) have carried out a study on SCPMS of Indian Automobile Industry. While several studies on SCPMS have been conducted specific to countries, regions

and industries, many such studies are not available in the Indian context (Sahay, Cavale, & Mohan, 2003). Saad & Patel, (2006) also highlights the need and importance for carrying out further study on SCPMS of other Indian Industries so that generic SCPMS can be developed for Indian Industries.

### 1.4.3 Identify suitable models for integration in SCPMS

Incorporating Mathematical Models and Heuristics in SCPM is expected to be beneficial. Preliminary study indicates suitability of the following OR and Heuristic Models as candidates for incorporation in SCPMS:

1. Analytical Hierarchical Process (AHP) (Hepler & Mazur, 2007; Islam & Rasad, 2005; Saaty, 2008)
2. Data Envelopment Analysis (DEA) (George & Rangaraj, 2008; Talluri, 2000)
3. Queuing Theory (Hillier Frederick, Lieberman Gerald, & Hillier Frederick, S., & Lieberman Gerald, 2005)
4. Supply Chain Modelling and Simulation
5. Use of Fuzzy Logic and Fuzzy AHP
6. Balance Score Card (BSC) and Modified BSC (Chia, Goh, & Hum, 2009; Hepworth, 1998; Kaplan & Norton, 1993)
7. Performance Prism (PM) (Neely et al., 2000; Ryan, 2015)

There are instances available in literature of using DEA, AHP, Fuzzy logic and other mathematical models in Performance Measurement and Management. The performance measurement literature proves the scope and benefit in incorporating OR and Heuristics in PMS and developing such models.

### 1.4.4 Evaluation and validation of the integrated frameworks

Theoretical framework needs to be tested and evaluated in live situations. There are several SCPMS models presented in the literature. Many authors have evaluated its effectiveness and utility differently. Estampe, Lamouri, Paris, & Brahim-Djelloul (2010) have suggested a framework for evaluating SC performance frameworks and models. Expert opinion and exploratory survey can also be tools to validate the PMS frameworks. Demonstration of the models through sample data confirms the validity to certain extant.

## 1.5 Framework for SCPMS Development

Neely et al., (2000) proposed a framework for development of a PMS. This is a linear and hierarchical model which gives a flowchart for SCPMS development process. A generic framework, which is a modified version of the framework suggested by Neely et al., (2000) is kept as a guideline to the development of the SCPMS framework throughout this research. Figure 1.1 shows suggested scheme for development of SCPMS framework. The development process starts with defining organisation's mission statement. Based on company's strategic objectives (which follows from organisation's mission statement) and functional area's role, global performance measures are developed. Communication of the PMS objectives and SC objectives to all echelons of the organisation is critical to PMS implementation success. In addition to communicating the objectives of PMS, proper training and standard operating procedures (SOP) on specific measurement criteria and methods will be required. The feedback from the periodic reviews of the PMS will be an input to re-evaluate the various steps of the development process of SCPMS as shown in Figure 1.1 thus making the development process dynamic.

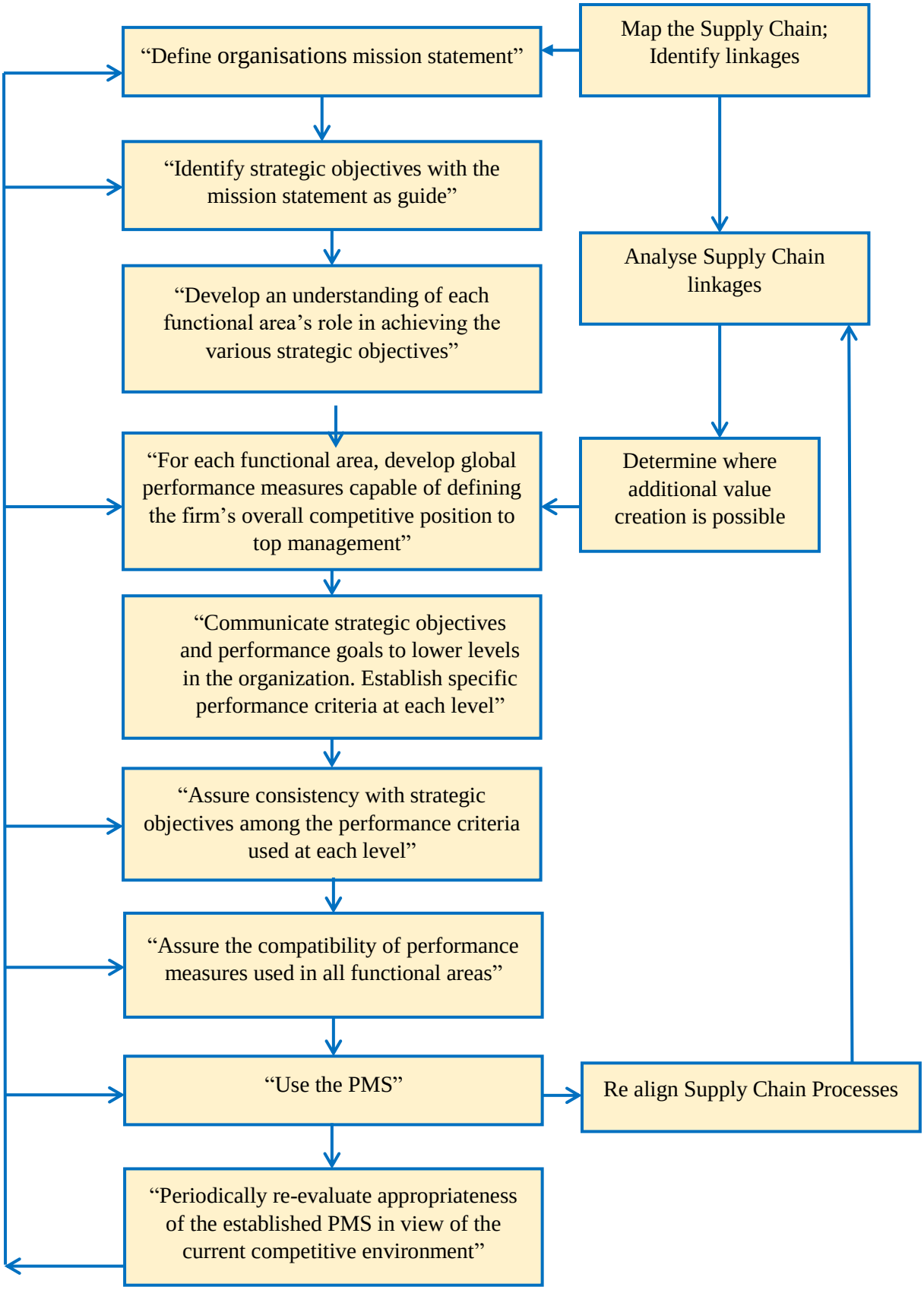



**Figure 1.1 Development Framework for SCPMS**

## 1.6 Motivation for Research

"*What gets measured gets improved*" - Peter Drucker.

Organisations now realise that, to compete in the present dynamic, globalised business environment, understanding and monitoring firm's performance is critical. Business performance, to a large extent depends on 'measurements' (Taticchi et al., 2010). Thus, there is a reasonable expectation to focus on the network and the SC in which the firm is a component (Charan et al., 2008). Last two decades witnessed significant increase in business performance measurements and monitoring (Taticchi et al., 2010).

People in organisations respond to measures. Kennerley & Neely, (2002) states that, "measures send people messages about what matters and how they should behave. When the measures are consistent with the organisation's strategies, they encourage behaviours that are consistent with strategy. The right measures then not only offer a means of tracking whether strategy is being implemented, but also a means of communicating strategy and encouraging its implementation. Studies suggest that some 90% of managers fail to implement and deliver their organisation's strategies". There can be many causes for this failure. One is: "strategies contain inherent assumptions about the drivers of improved business performance". The second key reason is: "the organisation's processes are not aligned with its strategies. And even if its processes are aligned, then the capabilities required to operate these processes are not". Therefore, the important issues are to ensure that Strategy is aligned to Goals and Processes and Capabilities are aligned to Strategy. Integration of Performance Measurement frameworks with multi criteria decision making models like AHP will help in prioritising and quantifying performance indicators in SC. Gunasekaran et al., (2001) argues that, "PMS can facilitate a greater understanding of the SC and improve its overall performance therefore achieving strategic objectives. Performance measurement is one of the core elements of managerial activity and the choice of PMS is central to achieving corporate strategic targets".

Even though in the last decade numerous and diverse PMSs have been proposed by different researchers, its implementation across SCs is yet to be a reality. Different PMSs proposed have created good interest, action and revenues, but not every time the intended success (Bourne et al., 2003; Kennerley & Neely, 2002). The reasons for this paradox are attributed to implementation difficulties and inherent limitations of existing PMS frameworks. In addition, many of the model are unable to provide weighting to the performance parameters

and does not communicate to the decision maker the contribution of given performance parameter in attaining organisational objectives.

Motivation for the study and development of models for SC performance measurement in selected industries is summarised as follows:

1. SCPMS is critical to effectiveness of SCs.
2. Measures spanning entire SC do not exist; requirement to go beyond internal matrix and take an SC perspective.
3. Existing measures usually have little to do with SC strategy and objectives and may even conflict result in inefficiencies.
4. Emerging (new) PMS frameworks are in an evolutionary stage and measure performance of adjacent channels only.
5. Measurements encourage desired behaviours; the goal of encouraging desired organisational behaviour across SCs.
6. Requirement to align activities / process with strategy ad SC goals.
7. Benefit of incorporating technology, Operations Research techniques and heuristics in PMS.

## 1.7 Overview of Research Work

The present research examines existing performance measurement frameworks in SCs, identifies strengths and gaps in order to develop appropriate models for SCPM. The comparative study of common frameworks and models for performance measurement helped to identify research gaps and focus of research agenda. Rational use of operations research techniques, heuristics and computer-based simulation techniques have been incorporated with existing highly cited frameworks of performance measurement. The present research develops SCPM models for the following areas:

1. Strategic Objectives and SC Performance
    a. Framework for Performance Measurement of Strategic Objectives using Analytical Hierarchical Process and Balanced Score Card (BSC)
    b. Aligning Performance Measurement Indicators with Strategic Objectives using Analytical Hierarchical Process and Performance Prism (PM)
2. Supply Chain Flexibility Performance Measurement

   a. Flexibility in supply chain and its measurement using Fuzzy Analytic Hierarchy Process (FAHP)
   b. “Measurement of Flexibility and its Benchmarking using Data Envelopment Analysis” (DEA)
   c. “Framework for flexibility performance in supply chains”
3. Sustainability Performance Measurement
   a. “Performance measurement systems for green supply chains using modified balanced score card and analytical hierarchical process”.
   b. Development of a framework for waste management in supply chains
   c. Performance Measurement Framework for Reverse Supply Chain
4. Survey of SC practices of Indian Industries
   a. Exploratory survey to get insights to SC practices of Indian Industries
   b. Validating of SC models developed

The performance measurement frameworks developed through this study can facilitate improved SCM capabilities to organisations. The study also presents suggestions for future research and presents an agenda for further study in SCPM. The research findings add to the body of knowledge and fill gaps in SCPM theory and its practice. A summary of the research frameworks is presented at Figure 1.2.

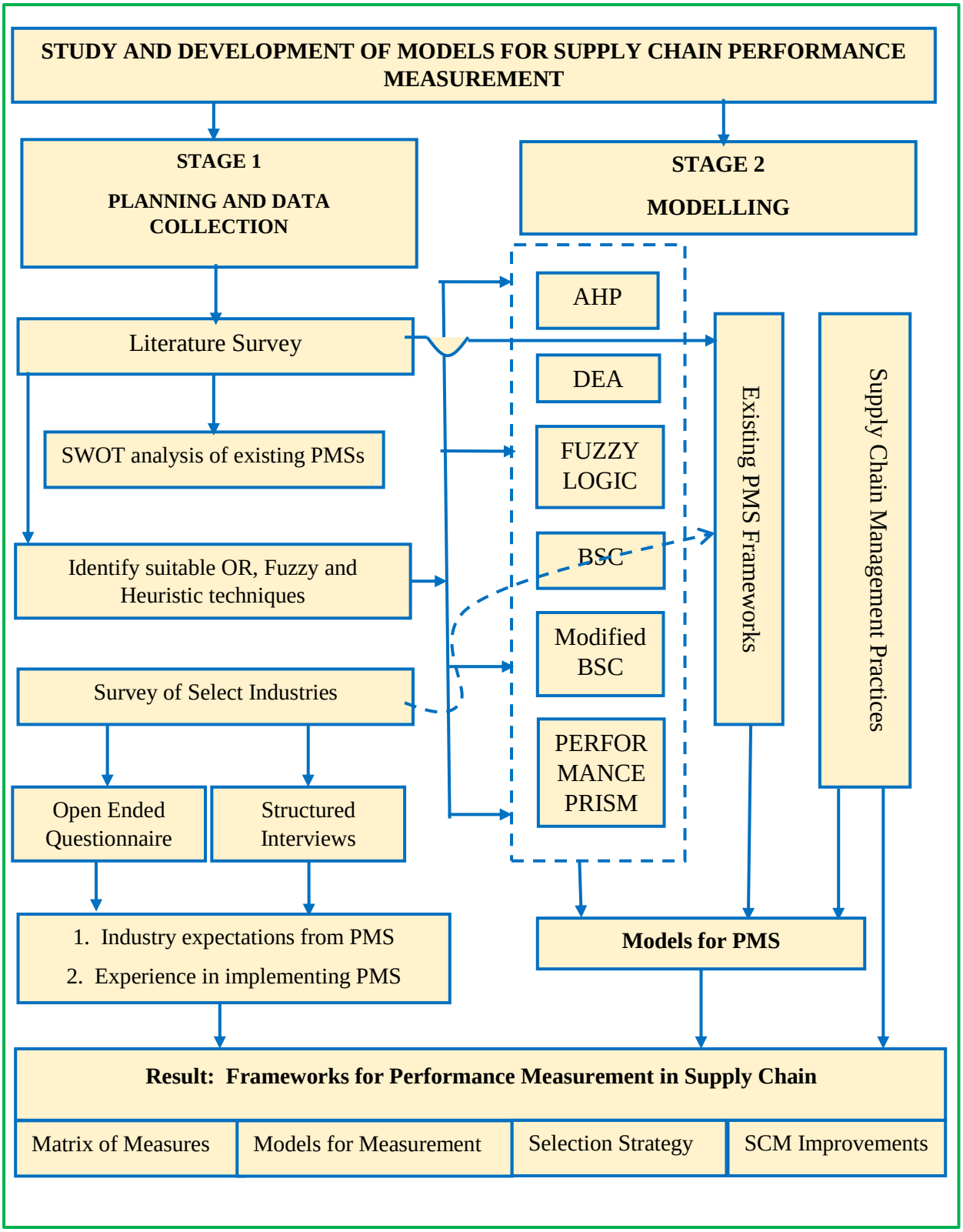



**Figure 1.2 Research Framework**

## 1.8 Organisation of Project Report

The organization of this present research work has been covered in eleven chapters depicted in Figure 1.3. A brief overview of all these chapters is given as follows:

**Chapter 1: Introduction**

Overview of the present research, motivation for research, research questions, research methodology adopted, framework for SCPMS development and structure of the thesis.

**Chapter 2: Literature Review**

Extensive examination of related literature to bring out objectives of SCPMS, Desirable characteristics of SCPMS, Evolution of SCPMS, Examination of performance measures and metrics, classification of SCPMS, Survey of some highly cited PMSs, Gaps identified in Literature, IT Tools for Performance Measurement, Implementation of SCPMS, Success Factors and Selection of SCPM System.

**Chapter 3**: **Performance Measurement Framework for Strategic Planning in Supply Chains**

Develops a framework to evaluate influence of selected performance parameters in attaining organizational goal, prioritise its resource deployment and comparing performance of supply chains. Demonstrates incorporation of AHP with BSC and PP.

**Chapter 4**: "**Supply Chain Flexibility Performance Measurement using Fuzzy Analytic Hierarchy Process"**

Proposes a method to determine flexibility performance measure of a supply chain using modified Fuzzy AHP. A comparative analysis of some widely-cited PMSs for SC flexibility is undertaken in this chapter. The usage of suggested measurement framework is also demonstrated using sample data**.**

**Chapter 5**: "**Measurement of Flexibility and its Benchmarking using Data Envelopment Analysis in Supply Chains"**

Demonstrates use of Data Envelopment Analysis (DEA) to facilitate effective measurement and benchmarking of SC flexibility. This chapter is broadly organised into a discussion on

DEA for performance measurement and demo of employing DEA for benchmarking flexibility in SC.

**Chapter 6**: "**A Methodology and Framework for Flexibility Performance Measurement of Supply Chains"**

"Proposes a framework and a methodology for flexibility performance measurement of SC. The framework identifies flexibility objectives and its contributing attributes at four levels of the SC and suggests taxonomy of flexibility performance measures. A methodology to prioritise the contribution of each performance attribute to achieve the desired flexibility objective using AHP has also been proposed and demonstrated in this study".

**Chapter 7**: "**Sustainability Performance Measurement in Supply Chains"**

Provides a brief of the sustainability measurement practices as applied to SC. A comparative analysis of some most widely cited Performance Measurement Systems (PMS) for Green SC is carried out in this Chapter and it indicates that the modified Balanced Score Card (BSC) as a suitable framework for Green SC PMS. This chapter demonstrates integration of Analytic Hierarchy Process (AHP) with modified BSC to facilitate effective Green SCPMS.

**Chapter 8**: "**Performance Measurement Framework for Reverse Supply Cain (Maintenance Management)"**

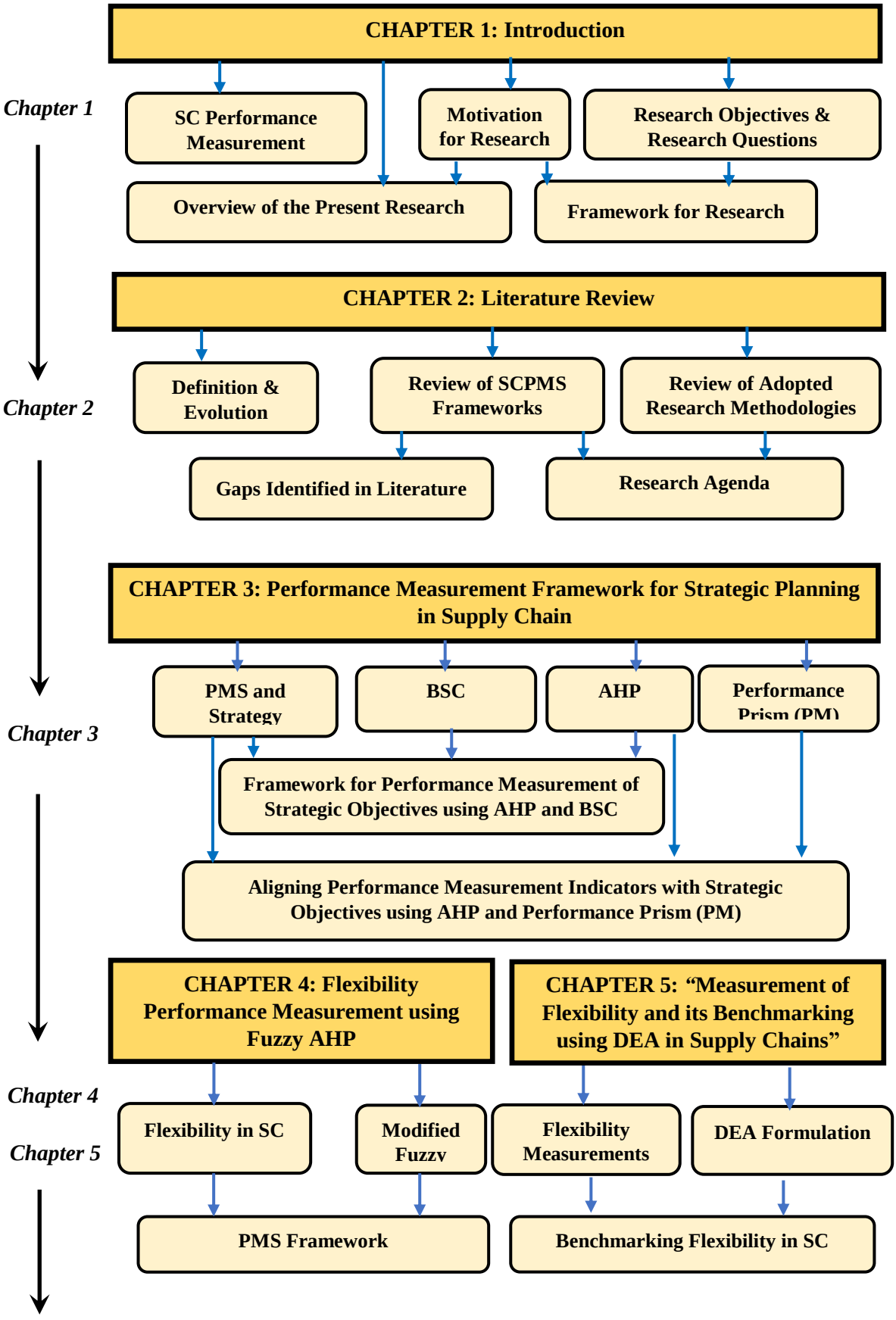
Demonstrates use of DEA for Maintenance Performance Measurement to facilitate measurement of relative efficiencies, define targets and benchmarking of similar Maintenance Units in a Supply Chain.

**Chapter 9: Survey of Supply Chain Performance Measurement Practices of Indian Industries**

Based on a survey, this chapter provides an analysis of performance measurement practices of Indian Supply Chains.

**Chapter 10: Contributions, Recommendations and Conclusion**

Major contribution of this research. boundaries and suggestions for future study are offered in this chapter


CHAPTER 1: Introduction
Chapter 1
SC Performance Measurement
Motivation for Research
Research Objectives & Research Questions
Overview of the Present Research
Framework for Research
CHAPTER 2: Literature Review
Chapter 2
Definition & Evolution
Review of SCPMS Frameworks
Review of Adopted Research Methodologies
Gaps Identified in Literature
Research Agenda
CHAPTER 3: Performance Measurement Framework for Strategic Planning in Supply Chain
Chapter 3
PMS and Strategy
BSC
AHP
Performance Prism (PM)
Framework for Performance Measurement of Strategic Objectives using AHP and BSC
Aligning Performance Measurement Indicators with Strategic Objectives using AHP and Performance Prism (PM)
CHAPTER 4: Flexibility Performance Measurement using Fuzzy AHP
CHAPTER 5: "Measurement of Flexibility and its Benchmarking using DEA in Supply Chains"
Chapter 4
Chapter 5
Flexibility in SC
Modified Fuzzy
Flexibility Measurements
DEA Formulation
PMS Framework
Benchmarking Flexibility in SC

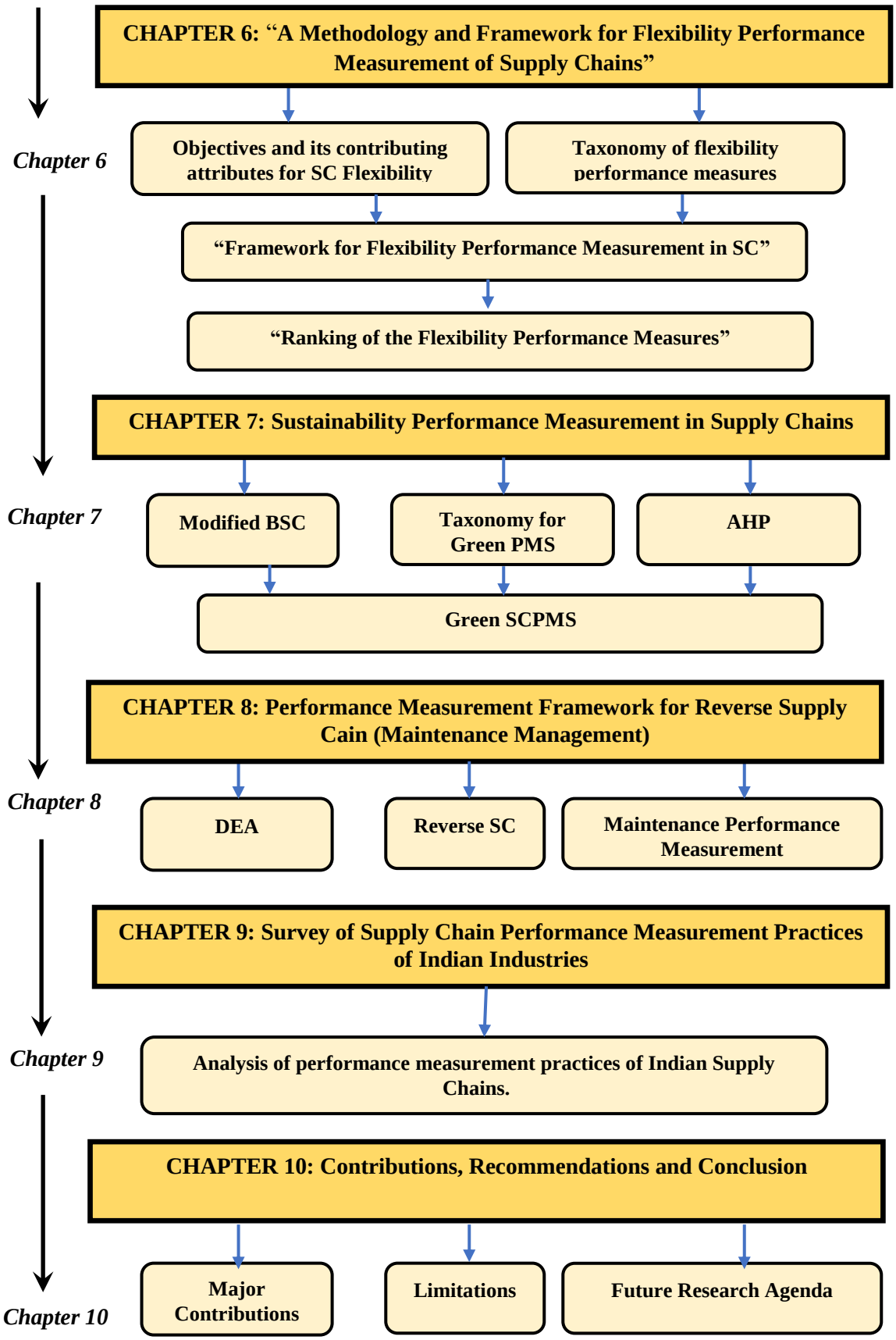



**Figure 1.3 Flow Diagram of the Thesis**

## 1.9 Conclusion

In this chapter, a complete overview of the present research has been presented. Initially, after the brief introduction of SC performance and SC performance measures, the research objectives are introduced. A set of research questions based on literature survey provides a direction for the research. The relevance of the present research and the motivation for the study are also presented in this chapter. The framework for SCPMS development presented provides a generic guideline and pattern for the research. This chapter also provides the organisation of the research work. The performance measurement frameworks developed through this research can facilitate improved SC management capabilities to organisations. The research findings add to the body of knowledge and fills gaps in SC performance management theory and practice.