Development of an Integrated Multi-Perspective Framework for Effective Performance Measurement System in Supply Chain Management

THESIS

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by
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CERTIFICATE

This is to certify that the thesis entitled **"Development of an Integrated Multi-Perspective Framework for Effective Performance Measurement System in Supply Chain Management"** and submitted by **Manoj Kumar Srivastava (ID No. 2003PHXF028)** for award of Ph.D. Degree of the Institute, embodies original work done by him under my supervision.

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Abstract

The aim of this research is to develop an integrated multi-perspective framework for effective supply chain performance measurement system and proposing its managerial implications. For this, interactions among various performance measures that influence the supply chain performance are identified.

While existing supply chain performance measurement models have focused on various measures, recently researchers have focused on Balanced Supply Chain Scorecard (BSCS) frameworks. This research proposes a three-tier Integrated BSCS Framework. As the focus of Balanced Scorecard approach is more holistic and integrative in contrast to other approaches, the framework is developed on the foundations of this approach. Innovation & learning, Process, Customer and Financial Perspectives considered in BSC make it a complete performance measurement tool for practicing managers. Interpretive Structural Modeling (ISM) methodology is used to understand the mutual influences among supply chain performance measures, both dependent (result) variables and independent (driving) variables. By analyzing the measures based on their driving-dependency powers, crucial measures can be identified that influence overall performance of supply chain. Superior productivity and performance can be achieved by continuously improving the driving variables.

Four such ISM models are developed, one for each perspective of BSC. The other two combined models are also developed for dimensions and the measures from all perspectives. These total six ISM models formulate an Integrated BSCS Framework to strengthen managerial decision making by projecting a complete picture of possible driver and dependent variables in supply chains.

The research validates the developed models in the framework through expert opinion survey. The developed framework is compared with two other well established frameworks, namely, Supply Chain Council's SCOR (Supply Chain Operations Reference) model and Beamon's ROF (Resource, Output and Flexibility) model. All these three frameworks are integrated for presenting a three axis universe of supply chain performance measures. Finally the implications, limitation and scope of the research are identified.

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Abbreviations

ABC .... **Activity-Based Costing**
APICS .... **American Production and Inventory Control Society**
APQC .... **American Productivity and Quality Centre**
BOM .... **Bill of Material**
BSC .... **Balanced Scorecard**
BSCS .... **Balanced Supply Chain Scorecard**
CFAR .... **Coordinated Forecasting and Replenishment**
COGS .... **Cost of Goods Sold**
CR .... **Contextual Relationship**
CRP .... **Continuous Replenishment Programs**
CVR .... **Customer Value Ratio**
DPO .... **Days Payable Outstanding**
DSO .... **Days Sales Outstanding**
ECO .... **Engineering Change Order**
EDI .... **Electronic Data Interchange**
EIS .... **Executive Information Systems**
EPC .... **Electronic Product Code**
ERP .... **Enterprise Resource Planning**
eSCM .... **Electronic Supply Chain Management**
EVA .... **Economic Value Analysis**

FTE .... **Full Time Equivalent**

GIS .... **Geographical Information Systems**

IS .... **Information Systems**

ISM .... **Interpretive Structural Modeling**

MACTOR ...... **Matrix of Alliances & Conflicts: Tactics, Objectives & Recommendations**

MICMAC .... ***Matrice D'impacts Croisés Multiplication Appliquée A Un Classement***

OAD .... **Optimal Asset Utilization**

OSBC .... **Open Standards Benchmarking Collaborative**

OWANs .... **Organization Wants and Needs**

RFID .... **Radio Frequency Identification**

RFQ .... **Request for Quotation**

R-O-F .... **Resource, Output and Flexibility**

ROI .... **Return on Investment**

ROS .... **Return on Sales**

SAP .... ***Systeme, Anwendungen Und Produkte***

SC .... **Supply Chain**

SCC .... **Supply Chain Council**

SCM .... **Supply Chain Management**

SCOR .... **Supply Chain Operations Reference**

SCPM .... **Supply Chain Performance Measurement**

SEM .... **Structural Equation Modeling**

SG&A .... **Sales, General & Administrative Expenses**

SKU .... **Stock Keeping Unit**

SMART .... **Strategic Measurement And Reporting Technique**

SSIM .... **Structural Self-Interaction Matrix**

SSM .... **Soft Systems Methodology**

SWANs .... **Stakeholder Wants and Needs**

SRM .... **Supplier Relationship Management**

TCO .... **Total Cost of Ownership**

TQM .... **Total Quality Management**

VMI .... **Vendor Managed Inventory**

WIP .... **Work in Process**

Notations

P_k	**:**	**Perspective**
D_j	**:**	**Dimension**
m_i	**:**	**Measure**
$^{kj}m_i$	**:**	**i^{th} measure (in j^{th} dimension of k^{th} perspective)**
$^{k}D_j$	**:**	**j^{th} dimension of k^{th} perspective**
$P^1(P_k)$	**:**	**The Level One Framework among Perspectives**
$P_c^2(D_j)$	**:**	**The Level Two Framework among Dimensions (Combined)**
$P_1^3(m_i)$	**:**	**The Level Three Framework for Innovation & Learning Perspective**
$P_2^3(m_i)$	**:**	**The Level Three Framework for Process Perspective**
$P_3^3(m_i)$	**:**	**The Level Three Framework for Customer Perspective**
$P_4^3(m_i)$	**:**	**The Level Three Framework for Financial Perspective**
$P_c^3(m_i)$	**:**	**The Level Three Framework among Measures (Combined)**

Chapter – 1

Introduction

In today's world, Supply Chain Management (SCM) is a key strategic factor for increasing organizational effectiveness and for better realization of organizational goals such as enhanced competitiveness, better customer care and increased profitability. The era of both globalization of markets and outsourcing has begun, and many companies select supply chain and logistics to manage their operations. Most of these companies realize that, in order to evolve an efficient and effective supply chain, SCM needs to be assessed for its performance.

1.1 Supply Chain Management

The concept of supply chain management has evolved from management practices like Total Quality Management and Just in Time, methodologies like Systems perspective and the functional area of management, logistics. The focus is either on how to increase throughput and decrease operation costs, or on how to decrease inventory for improving the performance of the system. The innovation in supply chain management is actually the system boundaries. Instead of focusing on a single organization and its performance, the view spanning over several organizations is used to fulfill the end consumers' demand.

The underlying concept of the supply chain embraces several points (Houlihan, 1985):

- The supply chain identifies the complete process of providing goods and services to the final user.
- The supply chain extends across organizational boundaries.

- The primary objective of the supply chain is service to the customer, which must be balanced against costs and assets.

- Objectives of individual supply chain members are achieved through the performance of the chain as a whole.

Shary and Skjött-Larsen (1998) state that as the complexity increases in the supply chain, the need to integrate each stage as part of a larger system increases as well, since the customer becomes remote. This results in a series of decisions taken on an individual basis, with non-aligned objectives. Therefore coordination is one of the primary tasks of supply chain management. So what does 'coordination' mean? The Longman Dictionary of Contemporary English offers, *to organize an activity so that the people involved in it will work together and achieve a good result*. If this is compared with the explanation of integration, *the combining of two or more things so that they work together effectively* - it is actually quite hard to separate them, and they are more or less interchangeable. During the late nineties the concept of 'collaboration' was proposed and discussed. Mentzer et al. (2000) define collaboration as occurring when "companies in the supply chain are actively working together as one toward common objectives". Regardless of the linguistics, it is quite possible to declare that ultimately supply chain management is about developing appropriate policies and procedures for managing the supply chain as a single entity.

1.2 Importance of Integration in SCM

Before the era of supply chain management, integration focused on the internal processes within a company. Melnyk and Wassweiler (1992) identify four types in the regular business context:

- ***Functional integration*** deals with the integration within a functional area such as marketing, manufacturing or logistics.

- ***Organizational integration*** deals with the links and extent of coordination between the different functional areas of the firm, for instance between manufacturing and marketing divisions.

- ***Strategic integration*** deals with the extent to which the processes of formulating, implementing, evaluating and revising strategic objectives between functional areas are integrated.

- ***Inter-organizational (channel) integration*** deals with the linkages that exist with external organizations. Two types of integration are mentioned: forward integration with customers and backward integration with suppliers.

This is one way of specifying the type of integration, but it is not the only one. It is also quite common to find models that describe the level or depth of integration. When using the Melnyk and Wassweiler (1992) model, it seems that channel integration and supply chain integration are very similar in scope, and that the other three aspects (functional, organizational and strategic) can all be transferred to the supply chain context. One example of functional integration in the supply chain context could be when a manufacturing department is carrying through its scheduling in cooperation with the supplier. Organizational integration in the supply chain context would occur when manufacturing is coordinating it's planning with the customer's marketing department. Strategic integration in supply chains could emerge when the supply chain, or parts of it, shares a common strategy to guide their decisions. So there are many types of integration. Armstead and Mapes (1993) found in a survey that there was an encouraging link between performance and integration factors.

1.3 Supply Chain Performance Measurement

If the performance of a system cannot be measured, it cannot be efficiently managed. Unfortunately, it is difficult to select appropriate supply chain performance metrics because of the complexity of the supply chain and ever-changing business environments. Beamon (1998) noted that the establishment of appropriate performance measures is an important element of supply chain design and analysis. An ability to effectively measure supply chain performance will be critical to any extended enterprise, and to the organizations within. Since conventional measurement systems may not be valid beyond organizational boundaries, a new performance measurement system is required.

Lambert and Pohlen (2001) summarized the need for new types of metrics for SCM as follows:

- The lack of measures that capture performance across the supply chain
- The requirement to go beyond internal metrics and take a supply chain perspective
- The need to determine the interrelationship between corporate and supply chain performance

Some other considerations while addressing these needs are:

- Requirement to align activities and share joint performance measurement information to implement strategy that achieves supply chain objectives
- Desire to expand the "line of sight" within the supply chain
- Requirement to allocate benefits and burdens resulting from functional shifts within the supply chain

In supply chain modeling, the issues that are receiving increasing attention are product postponement and flexibility measures in both volume and delivery flexibility. So further research is required on looking beyond sub-optimization, whether it is at the functional level within firms or at the process level among firms. The strategic link between supply chain performance measures and their impact on customer's satisfaction is a challenge to establish in right context.

1.4 Research Problem

This research attempts to propose and develop a generic integrated multi-perspective framework for hierarchical contextual relationships between supply chain performance measures. Research also aims to provide managerial implications of these contextual linkages, in order to make more effective decisions. In that sense the problem statement of the research can be stated as *"Development of an integrated multi-perspective framework for effective performance measurement system in supply chain management.*

1.5 Objectives of the Research

The research focuses on three objectives to achieve its purpose of an integrated framework development:

1. Critical analysis of existing performance measurement models in supply chain
2. Identification, evaluation and classification of supply chain performance measures
3. Development of a framework by establishing contextual relationships between key supply chain performance measures.

1.6 Research Process and Methodology

The research process consists of the following steps. First it critically analyzes various performance metrics, models and frameworks to arrive at comprehensive categorization of performance measures and key performance indicators. The next step clubs these identified measures with other measures gathered from literature review into the four perspective of Balanced Score Card (BSC) in context of the supply chain management. This improvisation in Balanced Supply Chain Scorecard is based primarily on the work of Brewer and Speh (2000). The **Meta-research Methodology**[1] is used to establish contextual relationships between performance measures. The meta-research methodology in this regard has referred Sixty-four Cases (1991-1997), Eighty Articles (Feb 2002-Feb 2006), Three Published Surveys (2003-2004) and research papers (1994-2001) of Six Pioneer Researches in the field of Supply Chain Performance Measurement. Based on inferences drawn from these sources, the contextual relationships between measures are established. All referred materials, with their details, are mentioned in Appendices.

After establishing these contextual relationships between measures hierarchical models are developed for the measures in each perspective of BSC. **Interpretive Structural Modeling (ISM) Methodology**[2] is used for this purpose. An integrated hierarchical framework of performance measures for each perspective is developed by constructing a reachability matrix and iterating it further to get final diagraph. Measures in all four perspectives are next integrated to get an overall framework of supply chain performance measurement system.

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1. This research has used Rogers' (1981) propositional inventory as a type of Meta -research. Meta-research is "a study on research and an analysis of analysis" (Rogers, 1981) and it can be defined as "the synthesis of primary research results into more general conclusions." (Rogers, 1981) Thus, meta-research could provide valuable information that cannot be obtained in another way. According to Rogers (1981), meta-research can be divided into two ways. The first way of meta-research is 'meta-analysis', which is "the statistical re-analysis of the original data from a number of studies bearing on the same problem." And the second way of meta-research is 'propositional inventory', which is "the synthesis of general conclusions from research where the original data is not available and hence where only written conclusions from each of the primary studies are available to the meta-researcher." According to Hollifield (2001), the propositional inventory method uses "the categorizing of discrete elements such as variables, methods, or findings in a specific study. Once similar studies have been broken down, the strengths and weaknesses of the body of research can be understood as a whole and, furthermore, gaps in knowledge can be identified."

The meta-research methodology has its limitations also. There exists Publication bias in meta-research as it leads to the censoring of studies with non-significant results. In a retrospective methodology such as meta-research, the synthesizer has the luxury of choosing what past studies to be included. Using gambling as an analogy, Root (2003) pointed out that computing probabilities based on known facts is like betting money in a game after the result is known. Berk and Freedman (2003) questioned the assumed independence of studies for research. Researchers are trained in similar ways, read the same papers, talk to each other, write proposals for the same funding agencies, and publish the findings to the same pool of peer-review journals. Earlier studies lead to later studies in the sense that each generation of doctoral students trains the next. They questioned whether this social dependence compromises statistical independence.

2. Interpretive structural modeling (ISM) is an effective methodology for dealing with complex issues. The methodology of ISM is an interactive learning process. In this, a set of different and directly related variables affecting the system under consideration is structured into a comprehensive systemic model. First proposed by J. Warfield (1974), ISM is a computer-assisted learning process that enables individuals or groups to develop a map of the complex relationships between the many elements involved in a complex situation. ISM is often used to provide a fundamental understanding of complex situations as well as to put together a course of action for solving a problem. It allows researchers and managers to gain a deeper understanding of the relationships among key issues, and portrays the structure of a complex problem under study in graphical mode. The methodology of ISM can act as a tool for imposing order and direction on the complexity of relationships among elements of a system (Sage, 1977 and Singh et al., 2003).

1.7 Outline of the Thesis

This section will describe the purpose of each chapter in this thesis.

Chapter 1: Introduction

This introductory chapter explains the relevance of the research problem in the context of developing a framework, research objectives, methodology and an outline of the thesis.

Chapter 2: Literature Review

An extensive review of the literature in the field of supply chain performance measurement in three broad categories namely, Supply Chain Management, Performance Measurement and Supply Chain Performance Measurement Systems is undertaken in this chapter. The research gaps are also identified for proposing a new framework.

Chapter 3: Proposed Integrated Balanced Supply Chain Scorecard (BSCS) Framework: Perspectives, Dimensions and Measures

In this chapter a three tier integrated multi-perspective framework is proposed for supply chain performance measurement. Existing supply chain performance measurement models, emerging issues, latest surveys and articles are scanned thoroughly to extract measures. Proposed three tier framework is based on the design principles mentioned in the literature on effective performance measurement system. Measures are classified in BSC perspectives to model them.

Chapter 4: Development of Integrated BSCS Framework using Interpretive Structural Modeling (ISM)

In this chapter, first contextual relationships among identified measures are established based on meta-research methodology. The ISM methodology is selected to bring out a meaningful structure for the proposed framework in each perspective of BSC. Iterations are done to determine appropriate level of each measure in the designated perspective. Two combined models are also plotted for dimensions and the measures from all perspectives. These total six ISM models, developed in this chapter formulate an *Integrated BSCS Framework* to strengthen managerial decision making.

Chapter 5: Analysis and Managerial Implications

Here the developed framework and strategic linkages are analyzed individually to interpret their significance towards better supply chain performance measurement. The MICMAC (*Matrice d'Impacts Croisés Multiplication Appliquée à un Classement*) analysis is done to classify measures in five categories based on their degree of influence / dependence on other variables. For all developed models, *managerial implications* are summarized from MICMAC analysis. The research validates the developed models in the framework through expert opinion survey. The developed framework is compared with two other well established frameworks, namely, Supply Chain Council's SCOR (Supply Chain Operations Reference) model and Beamon's ROF (Resource, Output and Flexibility) model.

Chapter 6: Conclusions and Recommendations

This chapter includes a discussion on contributions of the research. The limitations are mentioned by identifying its theoretical and implementation limits. This section also includes a discussion about future research.

Chapter – 2

Literature Review

SCM academics point out that individual autonomous companies are no longer the dominant entities - it is supply chains competing with other supply chains. This represents an important paradigm shift in business management. Not only does this shift represent a necessity, it also presents companies with opportunities to improve their performance and competitiveness. Indeed, “the more efficient a business is in managing its supply chain, the cheaper and more reliable the operation becomes. Money just seems to fall out of the cost structure and, of course, customers are happier too,” (Braithwaite & Mosquera, 1997).

The interest in managing supply chains is growing rapidly among companies around the world. Major forces behind this development are increasing competitive pressures and a belief that working cooperatively in supply chains can create a competitive advantage. Firms abandon the old antagonistic approach to doing business in favor of a more integrative management style focused on coordinating activities along the supply chain in order to attain or sustain their competitive position.

Coordinating activities in a supply chain, however, is difficult. The difficulties are partly due to the complexity induced by the large number of related and interdependent activities in the supply chain. The fact that the effects of certain actions are separated from their cause both in time and place increases complexity, and is made even worse by the functional division of responsibility along the supply chain. Understanding the interdependencies and the complex causal relationships in a supply chain is therefore crucial to the successful management of these activities.

2.1 Rationale of Supply Chain

The supply chain – a term now commonly used internationally - encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer. In the opinion of Handfield and Nichols (1999), this means that the supply chain, "encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain…Supply chains are essentially a series of linked suppliers and customers; every customer is in turn a supplier to the next downstream organization until a finished product reaches the ultimate end user".

New (1994), on the other hand, points out that supply chain is a metaphor employed to mean three main things:

- The supply chain from an individual company's perspective;
- A supply chain in relation to a product or item;
- The supply chain synonym representing functions: purchasing, distribution and materials management.

It is therefore evident that understanding supply chains is not straightforward. One has to be aware that supply chain is a label inconsistently used – as New (1997) suggests, 'pipeline' and 'demand chain' are ambiguous metaphors that could take the same definition as 'supply chain' because there is some connection and overlap in these metaphors and in the definition of supply chain. Croom et al. (2000) assert that this lack of universal definition stems from the multidisciplinary origin and evolution of supply chain management as a concept and, further, that this is, "reflected in the lack of robust conceptual frameworks for the development of theory on supply chain management".

2.2 Supply Chain Management

According to Braithwaite and Mosquera (1997), "Supply Chain Management (SCM) is about getting a smooth and efficient flow from raw material to finished goods in your customer's hands."

As a broad descriptor of supply chain management, one can say that the supply chain already exists; even management of the supply chain probably already exists to some extent in most companies, regardless of whether there is a designated overseer of a chain of organizations linked by their input into product development and the production of goods. Whilst supply chain management is therefore likely to exist, it is not necessarily recognized as such. Formally defining, naming and introducing the theory of supply chain management provides scope for its full implementation and further development.

Doing so raises the issue of the actual definition. Whilst defining 'supply chain' is relatively straight forward, 'Supply Chain Management' (SCM) is more complex. According to Christopher (1998), management of the supply chain implies process integration, both upstream with suppliers and downstream with distributors and customers - not just integration within the organization.

The overwhelming array of literature on the subject seems to imply that the management of the supply chain should mean the supply chain in its entirety (i.e. all those organizations necessary for the production of the value-added end product in the hands of the end customer), strengthening the links to the mutual benefit of all involved – including the end customer – by working in partnership in a way that has an innovative impact on external and internal organizational processes and functions.

In fact, all organizations are involved in one or more supply chains. Whether a company supplies raw materials, manufactures a product, sells a product or provides a service, it can be seen within the context of a supply chain.

There is much discussion about the precise meaning of supply chain management – managing the supply chain implies it is a process for managers to adopt – it is the integration of all links within the supply chain (externally) and nodes of the supply chain internally. More importantly, most commentators seem to use the term SCM synonymously with logistics. True SCM however, requires the integration of key business processes within a single organization and also across a network of organizations that constitute the supply chain. The challenge is to achieve this cross-functional integration (Lambert, 2001).

Searching for differences between SCM and logistics gets significant input by the Council of Logistics Management (CLM). In 1998, this organization modified its popular definition of logistics to a new one, making logistics a subset of SCM: “Logistics is that part of the supply chain process that plans, implements, and controls the efficient and effective flow and storage of goods, services, and related information from the point-of-origin to the point-of consumption in order to meet customer’s requirements” (Lambert et al., 1998).

The term ‘logistics management’ cannot be seen to encompass the range of activities that SCM comprises. In the past, practitioners would probably have seen little difference between the two since logistics focuses on goods from the point of origin to the point of consumption.

The contention among several authors, such as Croom et al. (2000), is that, like marketing, the field of SCM needs to be seen and studied as a discipline in its own right. The development in this field can be taken further forward if it is studied from robust underpinnings derived from relevant perspectives. In particular, the consolidation of current learning would enable the identification of possible gaps and allow researchers to pave the way rather than follow its path of development.

Lambert (2001) asserts that SCM was viewed as the individual company’s external logistics to include suppliers and customers. Over the last two decades SCM’s emerging definition has taken an holistic orientation of the integration and management of key business processes across the supply chain, i.e. the integration and management of key business process both internal and external to the individual company’s supply chain, i.e. management of the whole supply chain.

Supply chain is a linked set of resources and processes that begins with the sourcing of raw materials and extends through the delivery of end items to the final customer (Bridgefeld Group ERP/Supply Chain Glossary, 2004). While the separation of supply chain activities among different companies enables specialization and economies of scale, there are many important issues and problems that need to be resolved for successful SC operation – this is the main purpose of SCM.

According to the definition of SCM by the Global Supply Chain Forum (GSCF), SCM is “the integration of key business processes from end user through original suppliers that provide products, services, and information that add value for customer and other stakeholders” (Chan & Qi, 2003). SCM concept can only be justified, if there is a proactive relationship between a buyer and supplier and the integration is across the whole supply chain, not just first-tier suppliers (Cox, 2004).

2.2.1 Objectives of SCM

There has been a change of emphasis in the driver of the supply chain. Manufacturers were the focal point for product manufacture and distribution with quality being the competitive differentiator. Nowadays, it is the customer who is calling the shots.

A brief history as to how this paradigm shift came about is provided by Handfield and Nichols (1999). Four Decades back, organizations had begun to realize the benefits of capturing and maintaining customer loyalty, developing market strategies to that end. Design engineers cleverly translated customers' needs into high quality affordable product and service specifications.

Throughout the 1980s as demand for new products increased, manufacturers had to increase their responsiveness and flexibility by modifying or developing new products and processes in order to keep up with ever-changing customer needs. The manufacturers' suppliers and their input into these processes have an impact upon this responsiveness. Not only is there an upstream impact but also a downstream impact in terms of when, where and how the customer receives the end product in a cost-effective manner.

SCM seeks to meet the needs of the ultimate end customer through the integration of supply chain activities for the mutual benefit of all parties involved, namely the focal organization, its suppliers, their suppliers, your customers and their customers – all working together to achieve a sustainable competitive advantage.

The objective of SCM is to create the most value, not simply for the company but for the whole supply chain network, including the end customer. Consequently, supply chain process integration and re-engineering initiatives should be aimed at boosting total process efficiency and effectiveness across members of the supply chain (Lambert, 2001).

According to Slack et al (1998), SCM is about meeting three objectives:

- Focusing on satisfying end customers – because it is the customer who triggers action along the whole supply chain, each firm in the chain takes a cut in the purchase (or currency) of a product having kept their margin for the value they have added. The needs of that end customer need to be met throughout the supply chain processes;
- Formulating and implementing strategies that win and retain customer business;
- Taking a holistic approach to managing the entire supply chain effectively and efficiently.

2.2.2 Problems in SCM

There are several important problems in SCM that need to be resolved for efficient operation. Most of those problems stem either from uncertainties or inability to coordinate several activities and partners (Turban, McLean, & Wetherbe, 2004).

One of the most common problems in supply chains is the so-called bullwhip effect. Even small fluctuations in the demand or inventory levels of the final company in the chain are propagated and enlarged throughout the chain. Because each company in the chain has incomplete information about the needs of others, it has to respond with the unproportional increase in inventory levels and consequently even larger fluctuation in its demand to others down the chain (Forrester, 1961 and Forrester 1958). There are many practical examples from various industries that support this finding (see e. g. Jones & Simmons (2000) for an example of food industry or Naim, Disney & Evans (2002) for automotive sector). It was shown however that the production peak could be reduced from 45% to 26% by transmitting the information directly from the customer to the manufacturer (Forrester, 1961 and Holweg & Bicheno, 2002).

Another problem is that the companies often tend to optimize their own performance, disregarding the benefits of a supply chain as a whole (local instead of global optimization). Additionally, human factors should also be studied: decision-makers at various points in the supply chain are usually not making perfect decisions (due to the lack of information or their personal hindrances). Those two problems are also interconnected as employee reward systems often focus simply on growing sales or on gross margins (McGuffog & Wadsley, 1999).

A detailed review of other SCM-related problems can be found in (Holweg & Bicheno, 2002). Internet and e-business offer many possibilities for effective information sharing that enable seamless flow of transactions in the supply chain. They can also facilitate relationships by their ability to transfer information (Wagner, Fillis & Johansson 2003). Newly developed relationships can drastically change the underlying business processes and different new approaches are emerging, such as vendor managed inventory (VMI), computerized point-of-sale (POS) systems, supplier relationship management (SRM), manufacturing resource planning (MRP II) etc.

However it should be noted that information technology alone is not a panacea for all supply chain (SC) problems. Even more, the most often quoted problems of online purchasing are not related to technology but rather to logistic and supply chain problems (Hoek, 2001). This is even truer for traditional companies that are usually even less prepared for new e-commerce related challenges. The efficiency of supply chains can generally be improved by reducing the number of manufacturing stages, reducing lead-times, working interactively rather than independently between stages, and speeding up the information flow (Persson & Olhager, 2002).

2.2.3 Components of SCM

Johnson and Pyke (2000) have identified twelve areas in which supply chain literature review can be classified. These twelve categories are Location; Transportation and logistics; Inventory and forecasting; Marketing and channel restructuring; Sourcing and supplier management; Information and electronic mediated environments; Product design and new product introduction; Service and after sales support; Reverse logistics and green issues; Outsourcing and strategic alliances; Metrics and incentives and Global issues.

In each of these areas the respective literature, authors and the main theme are now classified to lay down foundation for supply chain performance measurement system review. Though these twelve areas are not comprehensive enough to address each and every issue of supply chain management due to its dynamicity, they are never the less representative to a larger extent.

Table 2.1: Supply Chain Management - Major Issues

1. Location	
Location pertains to both qualitative and quantitative aspects of facility location decisions. Optimization models play a role here, as do simple spreadsheet models and qualitative analyses. Decisions at this level set the physical structure of the supply chain and therefore establish constraints for more tactical decisions.	
v	Substantial treatment of GIS Models (Simchi-Levi et al., 1998)
v	Models of facility location, geographic information systems (GIS), country differences, taxes and duties, transportation costs associated with certain locations, and government incentives (Hammond & Kelly, 1990 and Drezner, 1996)
v	Issues of taxes, duties, exchange rates, and other global location issues (Dornier et al., 1998)
2. The Transportation and Logistics	
The transportation and logistics category encompasses all issues related to the flow of goods through the supply chain, including transportation, warehousing, and material handling. This may include many of the current trends in transportation management including vehicle routing, dynamic fleet management with global positioning systems, and merge-in-transit. Because of globalization and the spread of outsourced logistics, this category has received much attention in recent years.	
v	Logistics functions of many firms as the result of functional integration (Greis & Kasarda, 1997)
v	Role of logistics in gaining competitive advantage (Fuller, O'Conor & Rawlinson, 1993)
3. Inventory and Forecasting	
A few years ago, multiechelon inventory theory captured most of the research in this area that would apply to supply chains. However, in nearly every case, multiechelon inventory models assume a single decision-maker.	

Supply chains, unfortunately, confront the problem of multiple firms, each with its own decision-maker and objectives.

- Inventory theories (Silver, Pyke & Peterson, 1998 and Graves, Rinnooy Kan, & Zipkin, 1993)
- Sharing information with supply chain partners (Lee & Nahmias, 1993)
- Inventory and forecasting (Davis, 1993 and Fisher, Hammond, Obermeyer & Raman, 1994).

4. Marketing and Channel Restructuring

Marketing focuses downstream in the supply chain and proper channel selection and design is very much needed to ultimately achieve customer satisfaction.

- Fundamental thinking on supply chain structure (Fisher 1997)
- Interface with marketing that emerges from having to deal with downstream customers (Narus & Anderson, 1996)
- Channel management (Anderson, Day & Rangan, 1997)
- Supply chain structure in light of the well-studied phenomena of the bullwhip effect (Lee, Padmandbhan, & Whang, 1997)
- Issues related to pricing and trade promotions (Buzzell, Quelch, & Salmon, 1990)
- Channel initiatives such as vendor managed inventory (VMI), coordinated forecasting and replenishment (CFAR), and continuous replenishment (Fites, 1996, and Waller, Johnson & Davis 1999)
- Information on pricing, along with anti-trust and other legal issues (Train, 1998)

5. Sourcing and Supplier Management

Looks upstream to suppliers. The location category addresses the location of a firm's own facilities; this category pertains to the location of the firm's suppliers.

- Make/buy decisions (Venkatesan, 1992, Carrol, 1993, Christensen, 1994, Quinn & Hilmer, 1994, Kelley, 1995, and Robertson and Langlois, 1995)
- Global sourcing (Little, 1995 and Pyke, 1994)
- Relationship management (mcmillan, 1990 and Womack, et al., 1990)
- Determining the number of suppliers and the best way to structure supplier relationships (Cohen & Agrawal, 1996, Dyer, 1996, Fine, 1998, Magretta, 1998 and Pyke, 1998)
- Game theory to understand supplier relationships, contracts, and performance metrics. See, for instance, Cachon & Lariviere, 1996, Cachon, 1997 and Tsay, Hahmias, & Agrawal, 1999).

6. Information and Electronic Mediated Environments

This category emphasizes the advent of technological innovations like RFID, EPC and others to move towards the e-SCM paradigm.

- Longstanding applications of information technology to reduce inventory (Woolley 1997)
- Rapidly expanding area of electronic commerce (Benjamin & Wigand, 1997) and Schonfeld, 1998)
- Systems orientation, examining the role of systems science and information within a supply chain (Senge 1990).
- Integrative ERP software such as SAP (Whang & Lee, 1995), Baan and Oracle, as well as supply chain offerings such as i2's Rhythm and Peoplesoft's Red Pepper.

7. Product Design and New Product Introduction

Product design and new product introduction deals with design issues for mass customization, delayed differentiation, modularity and other issues for new product introduction.

- Increasing supply chain demands of product variety (Gilmore & Pine, 1997 and Fine, 1998) and customization (mccutcheon, Raturi & Meredith, 1994).
- Increased use of postponed product differentiation (Feitzinger & Lee, 1997)
- Interface with engineering and development, with clear implications for product cost and inventory savings. (Lee, Billington, & Carter, 1993)).
- Managing new product introduction and product rollover (Billington, Lee & Tang, 1998)

8. Service and After Sales Support
Service Supply chain management is getting a lot of attention due to the servitization of products and entire focus is on keeping human part alive in it.
v Benchmarking in service parts logistics (Cohen et al., 1997) v Spare parts and after sales service (Cohen & Lee, 1990)
9. Reverse Logistics and Green issues
Reverse logistics and green issues are emerging dimensions of supply chain management. Because of legislation and consumer pressure, the growing importance of these issues is evident to most managers. Managers are being compelled to consider the most efficient and environmentally friendly way to deal with product recovery which encompasses the handling of all used and discarded products, components and materials.
v Environmental issues (Corbett & van Wassenhove, 1993 and Herslinger, 1994) v Reverse logistics issues of product returns (Padmanabhan & Png, 1995), Clendenin, 1997 and Rudi and Pyke, 1998) v Product recovery management (Thierry, Salomon, Van Nunen, & Van Wassenhove, 1995) v Remanufactured products (Inderfurth, 1997) v Quantitative models for reverse logistics (Fleischmann et al., 1997)
10. Outsourcing and Strategic Alliances
Outsourcing and strategic alliances examines the supply chain impact of outsourcing logistics services. With the rapid growth in third party logistics providers, there is a large and expanding group of technologies and services to be examined. These include fascinating initiatives such as supplier hubs managed by third parties.
v Multiple Alliances (Cooper et al., 1997) v Strategic relationships with logistics providers Bowersox, 1990)
11. Metrics and Incentives
Metrics and incentives examine measurement and other organizational and economic issues. What cannot be measured - cannot be controlled is the theme in this category.
v Measurement within the supply chain (Meyer, 1996) v Link between performance measurement and supply chain improvement (O'Laughlin, 1997 and Johnson & Davis, 1998)
12. Global Issues
Global issues examine how all of the above categories are affected when companies operate in multiple countries. Currency exchange rates, duties & taxes, freight forwarding, customs issues, government regulation, and country comparisons are all included
v Country specific issues, to encompass issues related to cross-boarder distribution and sourcing (Arntzen et al., 1995) v Challenges in specific regions of the world (Asia - Lee & Kopczak, 1997, Europe – Sharman, 1997)

Supply chain management is an growing field, both in research and in practice. Major international consulting firms have developed large practices in the supply chain field, and the number of research papers in the field is growing rapidly. These areas appear to be somewhat disparate, but they are all linked by the integrated nature of the problems at hand. Firms operate in global environments, deal with multiple suppliers and customers, are required to manage inventories in new and innovative ways, and are faced with possible channel restructuring. The field promises to continue growing as the research advances and as firms continue to apply new knowledge in their global networks. Finally, as the Internet changes fundamental assumptions about business, firms operating in supply chains will be required to understand this new phenomenon and respond accordingly. Appendix A gives SCM research focus today. It gives a summary of recent contributions by few selected authors.

2.3 Performance Measurement Systems

Sink (1991) suggests that performance measurement is a "mystery…complex, frustrating, difficult, challenging, important, abused and misused". Terms which must be defined include performance measurement, performance measures, and performance measurement systems:

- ***Performance measurement*** has been defined as "the systematic assignment of numbers to entities" (Zairi, 1994). Churchman (1959) further suggests that the function of measurement is to "develop a method for generating a class of information that will be useful in a wide variety of problems and situations".

- ***Performance measures*** have been defined as "characteristics of outputs that are identified for purposes of evaluation" (Euske, 1984). Hronec (1993) defines performance measures as the vital signs of the organization, which "quantify how well the activities within a process or the outputs of a process achieve a specified goal".

- ***Performance measurement systems*** aim to "integrate organizational activities across various managerial levels and functions" (McNaiir et al., 1989). The need for integration is supported by Hronec (1993), who defines a performance measurement system as a "tool for balancing multiple measures (cost, quality, and time) across multiple levels (organization, processes and people)". Edson (1988) and Talley (1991) stress the need for performance measurement systems to focus attention on continuous improvement. Green et al. (1991) suggest that performance measurement systems should "target the value-added activities of the company". Kaplan (1991) states that an effective performance measurement system "should provide timely, accurate feedback on the efficiency and effectiveness of operations".

2.3.1 The Need for Measurement

The importance of measurement has been discussed along the following dimensions:

- ***Planning, control and evaluation:*** The process of analyzing measurement in order to make decisions is known as "evaluation". Euske (1984) states that "the measurement process is central to the operation of an effective and efficient planning, control, or evaluation system".

- ***Managing change:*** Maisel (1992) and Sieger (1992) suggest that performance measures must support management initiatives including total quality management (TQM). Olian and Rynes (1991) state that total quality (TQ) organizations measure more (and different) processes and outcomes than non-TQ organizations, and the primary requirement is to integrate measures vertically (across levels) and horizontally (across functions).

- ***Communication:*** Daniels and Rosen (1988) suggest that measurement is required to reduce emotionalism and increase constructive problem solving, increase influence, monitor progress, and give feedback and reinforce behavior. Juran (1992) suggests that "vague terminology is unable to provide precise communication. It becomes necessary to say it in numbers".

- ***Measurement and improvement:*** Sink and Tuttle (1989) suggest that "perhaps the only really valid, reason for measuring performance…is to support and enhance improvement". McNair et al. (1990) state that if measurement is "not part of continuous improvement, then the critical linkage between performance and evaluation is broken". Miller (1992) states that measuring performance "provides a scorecard to report how well improvement efforts are working. Performance measurement is an integral part of continuous improvement". Harrington (1991) states that measurement is "the beginning of improvement, because if you cannot measure the activity, you cannot improve it".

- ***Resource allocation:*** Thor (1991) states that measurement "helps an organization direct its scarce resources to the most attractive improvement activities … it also provides a direct stimulus to action".

- ***Measurement and motivation:*** Performance measurement can profoundly affect the motivation of individuals. Locke et al. (1981) and White and Flores (1987) have shown that performance improves if individuals are given targets, and is maximized if targets are seen as challenging but achievable. However, as Euske et al. (1993) state, the impact of performance measurement on organizational behavior depends on the organizational context of the measurement, the use made of measurements, the degree of agreement between measurements and organizational objectives, and the individual's motivational response to measurement.

- **_Long-term focus:_** Managers are often criticized for excessive focus on short-term results (Merchant and Bruns, 1986). Appropriate performance measurement can ensure that managers adopt a long-term perspective (Schuler et al., 1991). Performance measurement is a vital management tool. However, although individual measurement tools (such as quality costing) have been developed to support SCM, an integrated performance measurement system suitable for use in organizations has yet to be developed.

2.3.2 The Historical Development of Performance Measurement

Management accounting procedures and techniques has long dominated the field of performance measurement. Most such techniques were developed in the early years of the century, and have largely remained unaltered despite dramatic changes in the nature of business organization and management (Kaplan, 1994). The limitations of management accounting information for use in the management of operations have been discussed by many authors e.g. (Johnson & Kaplan, 1987). The field of performance measurement has also been dominated by the concept of management control systems. These systems, such as those proposed by Anthony (1965) appear, however, to be increasingly anachronistic due to their focus on “control” as opposed to “improvement” which is a goal of most organizations, especially those which have implemented TQM (Oakland, 1993). The need to adopt a balanced range of financial and non-financial performance measures is now widely accepted (Eccles, 1991). However, the move towards acceptance of non-financial performance measures requires a paradigm shift in organizational thinking. This paradigm shift, towards the acceptance of change in strategies, actions and performance measures has been termed cutting the “Gordian Knot” of misguided performance measurement (Dixon et al., 1990).

A wide body of literature on “new” approaches to performance measurement has been developed in recent years. Probably the most well-known approach to performance measurement developed in recent years is the “balanced business scorecard”, proposed by Kaplan and Norton (1991). The balanced scorecard was developed for the purpose of strategic performance reporting. Kaplan and Norton divide measures into four categories of perspective: financial; customer; internal business and innovation & learning.

The balanced scorecard has found some support in industry and academia (Maisel, 1992). However, the scorecard in itself does not provide a complete performance measurement system, but rather a tool for senior managers to monitor performance against strategic and operational objectives, and has been criticized for over simplicity (Brignall, 1992). The scorecard is useful, however, in providing a range of financial and non-financial areas of performance to be monitored. A second model is the “performance pyramid”, which was developed by Wang in the 1980s (Lynch & Cross, 1991). The performance pyramid shows a hierarchy of measures from the strategic to operational levels, and allows managers to focus on areas of high leverage. Again, however, the model can be criticized for oversimplifying the task of performance measurement, into merely a scoreboard for managers. The only example of a performance measurement system developed specifically for services was that proposed by Fitzgerald et al. (1991). Fitzgerald et al. differentiate between “feedback” and “feedforward” control. Feedforward control involves the development and deployment of plans and objectives, while feedback control involves the measurement of performance against those objectives. The model provides a conceptual framework for performance measurement, but not a measurement system design.

Throughout history, performance measures have been used to assess the success of organizations. The modern accounting framework dates back to the Middle Ages and since that time assessment of performance has predominantly been based on financial criteria (Bruns, 1998). Double entry accounting systems were developed to avoid disputes and settle transactions between traders (Johnson, 1983). By the start of the twentieth century the nature of organizations had evolved and ownership and management were increasingly separated. As a result, measures of return on investment were applied so that owners could monitor the performance that managers were achieving (Johnson, 1983). Since that time the vast majority of performance measures used have been financial measures of this type. By the 1980s there was a growing realization that the traditional performance measures were no longer sufficient to manage organizations competing in modern markets (Johnson & Kaplan, 1987). With more demanding customers and more competitive markets came the need for greater responsiveness and external focus for activities. Many authors recognized that, whilst traditional financial accounting systems indicate the performance that results from the activities of an organization, they provide little indication of how that performance is achieved or how it can be improved. The deficiencies in traditional financial performance measures, and their inadequacies given the changes to the competitive challenges facing companies, have been widely documented. Authors suggest that traditional financial performance measures are historical in nature (Dixon et al., 1990); provide little indication of future performance; encourage short termism (Hayes & Abernathy, 1980, Kaplan, 1986); are internally rather than externally focused, with little regard for competitors or customers (Kaplan & Norton, 1992; Neely et al., 1995); lack strategic focus (Skinner, 1974); and often inhibit innovation (Richardson & Gordon, 1980). It is widely believed that the information provided by such cost based systems is insufficient for the effective management of businesses in rapidly changing and highly competitive markets.

2.3.2 The Functions of Performance Measurement System

These shortcomings in traditional measures have resulted in a crisis in performance measurement and a subsequent revolution to overhaul existing systems to ensure that they reflect organizations' competitive circumstances (Eccles, 1991 and Neely, 1999). This revolution has led many organizations to invest large amounts of effort and resources into the design and implementation of new performance measurement systems. Data from the USA research company Gartner group, for example, suggest that 40 percent of the largest businesses in the USA had adopted the balanced scorecard by the end of 2000. Data collected by the Balanced Scorecard Collaborative put the figure even higher; suggesting that over 50 per cent of surveyed firms worldwide had adopted the balanced scorecard by the middle of 2001, with a further 25 percent considering it (Downing, 2001). Many processes (Bourne et al., 2000) and frameworks (Kennerley & Neely, 2000) have been proposed which are designed to help organizations implement an appropriate measurement system. At the heart of these processes and frameworks, as with much that has been written on the subject of performance measurement, is the premise that measures and measurement systems must reflect the context to which they are applied (Neely, 1999). Despite all of the time and effort spent redesigning measurement systems, there is little evidence that organizations are managing their measurement systems to ensure that they continue to reflect the organizational context as that context changes. Organizations are implementing new measures to reflect new priorities but failing to discard measures reflecting old priorities (Meyer & Gupta, 1994). As a result, it is suggested that organizations are drowning in data (Neely et al., 2000). Meyer and Gupta (1994) observe that failure to effectively manage this change causes the introduction of new measures "that are weakly correlated to those currently in place'' so that an organization will have a diverse set of measures that are not consistent. As with measurement systems introduced at the turn of the century, there is a danger that failure to effectively manage the way in which measurement systems change over time will cause new measurement systems to lose their relevance. The message from the history of performance measurement suggests, therefore, that measurement systems must reflect the context and objectives of the organization in question. At the point of implementation, systems tend to fulfill this requirement. History would suggest that such failure to effectively manage performance measurement systems over time will bring further measurement crises and the subsequent need to invest in redesign projects in the future. This raises two important research questions:

- What factors affect (facilitate and inhibit) the way in which measurement systems change over time?
- How can organizations manage their measurement systems so that they continually remain relevant?

These are important questions to answer if history is not to be repeated and organizations are to avoid the expense of another extensive overhaul of their measurement systems. Numerous authors espouse the need for reflection on measures to ensure that they are updated to reflect this continuous change (Meyer & Gupta, 1994, Ghalayini & Noble, 1996, Dixon et al., 1990 and Wisner & Fawcett, 1991) and audit tools have been proposed to facilitate this change (Dixon et al., 1990 and Bititci et al., 2000). However, with a few notable exceptions (Meyer & Gupta, 1994; Townley & Cooper, 1998; Bourne et al., 2000), empirical investigation of the evolution of measurement systems over time remains a considerable gap in performance measurement research (Neely, 1999).

Why is it important to look at the underlying concepts and the functions of measurement? Indeed, many managers and academics alike do not doubt that performance measurement is necessary and therefore do not seek for any deeper justifications. Garvin (1993) coined a phrase in the Harvard Business Review that has become paradigmatic for this view: “If you can’t measure it, you can’t manage it.”

Whereas on the one hand there are the overexcited protagonists of performance measurement, on the other hand there also exist the antagonistic cynics: the managers or employees who believe that performance measurement is a fundamentally flawed concept. They believe that as soon as objectives and evaluation methods are defined, managers and employees will find their way around, either through gaming, or ‘creative accounting’ and fraud. Or that the measurement will lead to tunnel vision (neglecting other areas which are not measured), disinclination on experimenting, or myopia. (Smith, 1998 and Austin 1994). Both views seem to be extreme: Performance measurement is surely not the safe secret to success. However, most managers would probably feel very uncomfortable without this instrument. The key to the evaluation of performance measurement lies in first identifying the function of the performance measurement system. And this, again, depends largely on the organizational context, the organizational culture and management intent. The confusion or disagreement about the sense and benefit of performance measurement stems from the fact that there is dissent on the purpose of measurement and on the question of how performance measurement actually works.

There is an extensive amount of normative literature on individual performance measures, performance measurement systems and frameworks, as well as the relationship between performance measurement systems and the environment (Neely et al. 1995). The literature offers several performance measurement frameworks, like Kaplan and Norton's (1996) "Balanced Scorecard", the "Performance Measurement Matrix" (Keegan et al. 1989) or the "Performance Pyramid" (Cross & Lynch 1992). Furthermore a number of checklists, guidelines and evaluation criteria are a available for suggesting principles to be employed when designing or evaluating metrics and performance measurement systems (e.g. Ghobadian & Ashworth, 1994, Meyer, 1994, McMann & Nanni, 1994, Caprice & Sheffi, 1994 and Caprice & Sheffi, 1995).

Authors in the field of performance measurement have specified several functions that performance measurement is supposed to fulfill. Some of them are listed in Table 2.2. There is no commonly accepted language or conceptual framework concerning the functions of performance measurement. As a result of literature review, the functions mentioned in the literature can be clubbed into eight categories, namely Strategy Formulation and Clarification; Management Information; Vertical Communication; Horizontal Communication; Decision Making and Prioritizing; Coordination and Alignment; Motivation and Learning

Interesting enough, there is almost no study which examines in detail, whether performance measurement in reality indeed fulfils all these functions and whether performance measurement systems in place really work in ways often presumed by normative literature. Only a few empirical studies can be found which are explicit on the use and functions of performance measurement (van Drongelen 1998 and Kald & Nilsson 2000). And even these are not based on first-hand empirical (case study) data but are based solely on the perceptions of managers.

In General management, three purposes of metrics can be identified as (Melnyk et al., 2004): for control, for communication and for improvement. According to Melnyk et al. (2004) literature has until now mainly focused on the use of metrics, but less on generating metrics and putting them into execution. They mention several reasons for an increased interest in performance measurement: Ever changing and ever increasing demands of customers; The moving focus from internal operations to a chain of collaborating companies; Decreasing product life cycles; Increased amount of data (not necessarily data quality) and Growing number of options a company can choose from.

Table 2.2: Functions of Performance Measurement System

1. Strategy Formulation and Clarification
v Translate vision and strategy in operationalisable objectives and actions (Kaplan & Norton, 1996 and Lingle & Schiemann, 1996)
v Clarify strategies (Kaplan & Norton, 1996 and Lingle & Schiemann, 1996)
v Force specificity and help to surface and resolve hidden disagreements among top management (Lingle & Schiemann, 1996)
v Specify values (Lingle & Schiemann, 1996)
v Help to define the goals and performance expectations for organizations (Medore and Steeple, 2000)
2. Management Information
v Provide management information (Bonsdorff & Andersin, 1995)
v Feedback for management for improved control (Kaydos, 1999)
v Provide information for planning and forecasting (Kaydos, 1999)
v Identify performance gaps (Bonsdorff & Andersin, 1995 and Kaydos, 1999)
3. Vertical Communication
v Communicate strategy throughout organization (Kaplan & Norton, 1996 and Neely & Najjar, 2000)
v Ensure clarity of communication of strategy from top to bottom of organization (Lingle & Schiemann, 1996)
v Communicate clear targets for actions, decisions and improvement activities (Kaplan & Norton, 1996)
v Communicate performance expectations (Bonsdorff & Andersin, 1995)
v Clarify responsibilities and objectives (Kaydos, 1999)
v Give employees certainty about how to contribute (Lingle & Schiemann, 1996)
v Provide basis for rational argumentation with superiors and employees (Kaydos, 1999)
v Provide common language for communication (Lingle & Schiemann, 1996)
4. Horizontal Communication
v Communicate strategy throughout organization (Kaplan & Norton, 1996 and Neely & Najjar, 2000)
v Provide common language for communication (Lingle & Schiemann, 1996)
v Provide basis for rational argumentation with other departments (Kaydos, 1999)
v Clarify responsibilities and objectives (Kaydos, 1999)
5. Decision Making and Prioritizing
v Support decision making (Bonsdorff & Andersin, 1995)
v Provide information for resource allocation decisions (Kaydos, 1999)
v Quantify efficiency and effectiveness of actions and assess the performance of an organization as a whole to assist decision making (Kennerly & Neely, 2000)
6. Co-ordination and Alignment
v Provide alignment of objectives and actions throughout organization (Kaydos, 1999, Lingle & Schiemann, 1996 and Kaplan & Norton, 1996)
v Simplify delegation of actions and decisions while still being in control (Kaydos, 1999)
7. Motivation
v Motivate employees (Bonsdorff & Andersin, 1995)
v Show employees' contribution to overall organization's performance (Bonsdorff & Andersin, 1995)
v Provide basis for performance related pay (Kaplan & Norton, 1996 and Lingle & Schiemann, 1996)
v Motivate employees by making their accomplishments clear (Kaydos, 1999)
v Improve knowledge of capabilities (Kaydos, 1999)
8. Learning
v Improve understanding of business processes (Kaydos, 1999)
v Challenge strategy (Neely & Najjar, 2000)

Cokins (2004) of the SAS institute described performance management as a framework that tightly integrates the business improvement and analytic methodologies that executives are already familiar with. These include strategy mapping, balanced scorecards, costing (including activity based cost management), budgeting, and forecasting, and resource capacity requirements.

Miller (2000) identifies the need of capturing critical quantitative performance data across (and between) functions and having qualitative insight into supplier and partner relationships for supply chain performance improvements. These relationships must lay foundation for long term and sustainable initiatives in this direction. Toni and Tonchia (2001) found that the main performance management systems in the literature can be grouped into five categories:

- Models that are strictly hierarchical (or strictly vertical), characterized by cost and non-cost performances on different levels of aggregation, till they ultimately become economic-financial.
- Models that employ a balanced scorecard or *tableaux de bord*, where several separate performances are considered independently; these performances correspond to diverse perspectives (financial, internal business processes, customers, learning/growth) of analyses.
- Models that can be called ‘frustum’, where there is a synthesis of low-level measures into more aggregated indicators, but without the scope of translating non-cost performance into financial performance.
- Models that distinguish between internal and external performances.
- Models that are related to the value chain.

2.3.3 Performance Measurement in Supply Chain Context

Supply chains may be typically categorized into either efficient or responsive supply chains (Fisher, 1997). Christopher and Towill (2002) make a similar distinction into lean and agile. Logistics service providers must be aligned with the supply chain they serve. For this alignment to happen flexibility, efficiency and responsibility-level measurements are must. Weber (2002) uses a hierarchical model to measure supply chain agility. The SCOR (Supply Chain Operations Reference) model further provides insight into metrics and indicators of supply chains (SCOR - Supply Chain Council, 2003; Stewart, 1995) However, the SCOR model was originally developed for manufacturing processes and therefore it might not be directly applicable to logistics service provision (Lai et al. 2004). Strong partnerships form the basis of supply chain management. Partnership evaluation criteria are (Gunasekaran et al., 2001): level and degree of information sharing (Mason-Jones and Towill, 1997), buyer-vendor cost saving initiatives (Thomas and Griffin, 1996), extent of mutual co-operation leading to improved quality (Graham et. al., 1994), entity and stage at which supplier is involved (Toni et al., 1994) and extent of mutual assistance in problem solving efforts (Maloni & Benton, 1997). However, Kemppainen and Vepsaelaeinen (2003) suggest, that it is neither feasible nor profitable to have strong collaboration with all supply chain partners. Logistical service providers should select key customers and focus on strengthening these relationships. Another important point regarding supply chain management is the use of information systems (Sanders & Premus, 2002). Information systems support the integration of inter-organizational processes (Hammer, 2001). Ross (2002) shows that IT investment can have a positive impact on market performance as a result of better coordination in the value chain. However, putting such a high level of collaboration into practice is not easy. Both information quality and relationship commitment play an important role (Moberg & Speh, 2002).

Measuring the operational performance of a supply chain is considered a very challenging task due to the number of stakeholders involved in the completion of the product or service. Initiatives such as SCOR guide supply chain managers in the definition of operational activities. SCOR and its partners have developed a framework that identifies key actions in several activities (plan, source, make, deliver). One of its objectives is to develop a list of supply chain metrics that can be used in different industries. SCOR and other supply chain initiatives allow engineers to redesign important business processes, especially those directly linked to their partners.

In order to identify performance measures for a supply chain, a good understanding of the most important research initiatives in logistics, manufacturing and operations activities is mandatory. The cross-boundary management required for an efficient supply chain means that a company’s management team must work across traditional internal functional areas and manage external interactions with both suppliers and customers. Hence, in order to monitor progress and adjust the development of a supply chain, performance indicators should generally be based on process performance, and not strictly on financial performance (Lummus, 1998).

Several fields of research have focused on quantifying the performance of individual firms, of specific departments of a company, of entire industries, and of key suppliers. The competitive environments of many industries now call for the evaluation of the performance of complete supply chains (from the suppliers' suppliers to the customers' customers). Van Hoek (1998) and Lambert and Pohlen (2001) have pointed out the difficulty of measuring and improving performance in a supply chain. To evaluate the performance of SCM systems, researchers have developed a number of conceptual frameworks.

Some research initiatives divide the performance of a supply chain into different categories. In their study of power influences in the supply chain, Maloni and Benton (2000) split performance measures into three categories: supplier performance, manufacturer performance, and supply chain performance (Lambert and Pohlen, 2001). Shin et al. (2000) also identify supplier and buyer performance measures. The supplier performance construct is composed of the following variables: lead times, on-time delivery, product quality, delivery reliability (fill rate) and product cost. Using a larger number of performance measures, Shin's framework allows for an even more complete assessment of buyer performance along the following dimensions: process flexibility and volume flexibility, production cost and production lead times, speed of delivery, delivery reliability and delivery lead times, and product quality (Shin et al., 2000). Finally, Spekman et al. (1998) investigate the role and characteristics of partnerships in supply chains. In this latter research initiative, two separate performance measures are identified to assess the performance of partnerships in a supply chain: cost reduction and customer satisfaction.

Numerous other research initiatives have combined different measures to assess the performance of various elements of a supply chain, such as customer responsiveness and costs (Davis, 1993). Lead times, stock-out probabilities and fill rates shape customer responsiveness whereas costs relate to inventory and operation expenses. Arntzen et al. (1995) in their study of a large computer company, concentrate on the amount of time consumed in executing supply chain activities.

Relevant work on mechanisms and techniques for inter-organizational control, such as in a supply chain context, has primarily been dominated by research on the general nature of inter-company relationships and especially the implication of trust (e.g. Lane & Bachmann, 2000, Doney & Cannon, 1997, Sako, 1992 and Spekman, 1988) or on specific areas of inter-organizational collaboration such as in Research and Development (e.g. Twigg, 1995, and Takeishi, 1998). More recently the use of management accounting and control techniques in supply chains have been studied (e.g. Mouritsen & Hansen, 2000, Ahmed et al., 1999, Cullen et al., 1999, Ahmed et al., 1997 and Berry, 1994). The issue of performance measurement has been relatively neglected, though. Although the importance of this topic is widely acknowledged, there is a clear lack of relevant respective empirical research. Ahmed et al. (1997) conclude from their literature review of inter-organizational management accounting and control that there are "significant gaps in theoretical and empirical knowledge".

In their book on Supply Chain Management, Handfield & Nichols (1999) state that "in effect, performance measurement is the glue that holds the complex value-creating system together, directing strategy formulation as well as playing a major role in monitoring the implementation of that strategy." Nonetheless, most research on performance measurement is only tackling specific individual parts of supply chain management issues. In particular the literature is dealing with performance measurement in three areas:

- Logistics (e.g. Caplice & Sheffi, 1994 and 1995; Fawcett & Clinton, 1996 and Odette, 2001)
- Total quality management (e.g. Bohoris, 1995; Wilson, 1998; Choi & Rungtusanatham, 1999).
- Purchasing, in particular supplier selection (e.g. Dickson, 1966, Ellram, 1990, Wilson et al., 1994, Weber, 1991 and Ellram, 1995).

Recent textbooks on supply chain management state the importance of performance measurement systems that integrate all these issues of supply chain management. Several authors recommend the Balanced Scorecard (BSC) as such a system (e.g. Handfield & Nichols, 1999 and Hines et al., 2000). They deal with this issue in a rather superficial way, though, without much consideration about possibly necessary changes to the BSC framework that have to be considered due to the differences between the intra-organizational management of companies as compared to the management of an inter-firm supply chain.

The most detailed and specific conceptual work on the use of a BSC for Supply Chain Management, so far, is presented by Brewer & Speh (2000). They introduce a modified BSC framework which incorporates “integrated measures” in each of the four perspectives of the BSC to include the “inter-functional” and “partnership” perspectives, and thereby “linking the Balanced Scorecard to Supply Chain Performance”. These types of measures are supposed to “show all members how the chain is performing” and foster “incentives to work with other members of the chain”. Brewer and Speh’s framework might well support top management in general SCM considerations, e.g. establish the basis for reengineering efforts. However, the basic concept of the BSC as we understand it, is the translation of corporate objectives and measures into targets and metrics on lower levels, which can be acted upon. Unfortunately, exactly this vital part for the success of the BSC, is left out by Brewer and Speh. One reason for this might be that there is a general tradeoff between integration and usefulness or guidance (Caplice & Sheffi, 1994). Measures such as “return on supply chain assets” (Brewer & Speh, 2001) might offer a highly integrative power in a SCM context but are of little or no operational guidance. There is almost no research on any real application of an integrated performance measurement system for supply chain management. Rather this area is identified as a gap in the literature (Lambert et al., 1998).

One of the reasons why the “management” and measurement of supply chains is by no means a trivial topic has been illustrated by Lee and Corey (1992). They see a major pitfall of any supply chain management effort in the fact that:

> "*although the supply chain's overall performance depends on the sites' joint performance, usually each site is managed by fairly autonomous management teams, each with its own objectives and mission. These objectives may have little to do with the supply chain's overall performance. Worse, these objectives may conflict. The consequence is that the different sites may have operational goals that, if met, result in inefficiencies for the overall chain.*"

This demonstrates how complex the issue of performance measurement in the supply chain really is. The theories on performance measurement within an organization already deal with issues such as principal-agency problems, hidden agendas of employees etc. In the supply chain context, one has almost by definition the case of multiple principles per agent (customers of suppliers) and multiple interest groups with diverging short and long-term objectives.

Although there is no comprehensive theory on inter-organizational performance measurement, some authors such as Handfield and Nichols (1999) proposed criteria for an "effective supply chain performance measurement":

- Measuring overall supply chain performance rather than only the performance of the individual chain member.
- One central, overriding focus for continual improvement of end-customer service.

- Allow managers not only to identify but also to eliminate causes of supply chain operational problems.

More specific demands on supply chain performance measurement are presented by other authors. According to them supply chain performance measurement should include:

- Changes in both the average volume of inventory held and frequency of inventory turns across the supply chain (Fawcett & Clinton, 1996);
- Adaptability of the supply chain as a whole to meet emergent customer needs (Bello & Gilliland, 1997 and Naylor et al., 1999);
- The extent to which supply chain relationships are based on mutual trust (Fawcett & Clinton, 1996).

Unfortunately, these authors generally do not present empirical studies to support their normative statements.

These conclusions are questionable, though, since no source of direct empirical evidence is provided to support the latter statements. Fawcett and Clinton (1996) presented data on the importance of performance measurement and the correlation between performance measurement practice and internal and external integration. However, no data was provided on the actual use of performance measurement and on the functions of measurement.

Furthermore, it is questionable how these requirements for "supply chain performance measurement" should be implemented. Basically there are two open questions: The first question deals with finding appropriate measures, which accurately measure supply chain or value chain efficiency and effectiveness. This question is tackled by mainstream literature.

The second question is: What are appropriate ways to implement these measures? A performance measurement system should always be seen in the context of the overall "performance management system" (Otley, 1998). To determine accurate measures for supply chain performance is different from knowing what measures are best to implement in a supply chain. Performance measures do not only have to reflect performance in an accurate way, they also have to be implemented in a way that takes into account the motivational issues of performance management. A company in the middle of the supply chain might view their immediate customers as end customers. Is it reasonable, then, to suggest that these companies should employ measures that reflect "overall supply chain performance"? Trying to increase overall supply chain performance does not necessarily mean to improve performance in terms of this company's (financial) objectives. Using overall supply chain performance measures as requested by Handfield & Nichols (1998) or Brewer & Speh (2000), seems only to be reasonable if for each company in the supply chain this particular chain is of sufficient priority, if there is appropriate co-operation in the supply chain, and if processes are in place to share the profits or cost savings that come from increasing overall supply chain performance. This is not necessarily the case in reality.

2.4 Research Gaps

It is unlikely that a single performance measure will be adequate for an entire supply chain. It is more likely that a system or function of performance measures will be necessary for the accurate and inclusive measurement of supply chain systems. Another investigative question is, what types of performance measures or performance measurement systems are appropriate for supply chain performance analysis, and why? Current supply chain performance measurement systems are inadequate because they rely heavily on the use of cost as a primary (if not sole) measure, they are not inclusive, they are often inconsistent with the strategic goals of the organization, and do not consider the effects of uncertainty. That is, although use of multiple supply chain performance measures may be commonplace in real-world settings, it is not commonplace in supply chain modeling. A performance measurement system for supply chain analysis must be developed that addresses these issues (Beamon, 1999).

While there is an ever-increasing number of supply chain models presented in the literature, there is very little available in supply chain performance measure selection. As such, many of the existing models use inappropriate or ineffective performance measures that are limited in scope (non-inclusive). Of course, the use of simple performance measures is tempting, since simple measures are more easily implemented into numerical models; however, by limiting the scope of the performance measurement, these models ignore important performance trade-offs (Giménez & Ventura, 2002).

The effects of these performance trade-offs are magnified when the supply chain is reconfigured on the basis of a non-inclusive measurement system. In order to improve the effectiveness of supply chain models, performance measures must be selected that will allow for a more complete and accurate analysis. Previous work in performance measurement has generally focused on developing new performance measures for specific applications, benchmarking and categorizing existing performance measures.

Other performance measures have been identified as appropriate for supply chain analysis, but have not yet been used in supply chain modeling research, since the qualitative nature of such measures make them difficult to incorporate into quantitative models. Examples of such measures are: customer satisfaction, information flow, supplier performance and risk management (Spekman, 1998). Cost, activity time, customer responsiveness, and flexibility have all been used as supply chain performance measures either singly or jointly. Yet the measures used thus far possess some significant weaknesses.

There is no adequate addressing of the need to designate or identify both owners of measures and customers of measure, the importance being that customers of measure should be involved in predetermining the expected or required performance. Joint determination between owners and customers of measures is crucial to producing the right outcome. Another gap in the literature is the near absence of a process orientation to measurement. The requisite supply chain orientation calls for a process view of performance spanning multiple firms. Combined with this need to address inter-firm process measures is the need to expand research in to measures of relationships. Economic, physical and psychological measures are equally important in planning and controlling the utilization, productivity and performance of logistics resources across the supply chain (Mentzer, 2001).

In supply chain modeling, there are a number of issues that are receiving increasing attention, as evidenced by their prevalent consideration in the work reviewed here. These issues are product postponement, global versus single-nation supply chain modeling and demand distortion and variance amplification. Traditional performance measures would reflect cost reduction while a more “enlightened” view should also deem revenue-enhancing elements as very important. Although many individual supply chain performance measures exist for resources and output, the number of flexibility measures actually applied to supply chains is few. Also there is very few volume flexibility and delivery flexibility measures for supply chains, and need is there to develop measures for mix flexibility and new product flexibility.

So further research is required on looking beyond sub-optimization, whether it is at the functional level within firms or at the process level among firms, and understanding supply chain outcomes and impacts on the customer, on the environments in which supply chain compete and on the individual supply chain members including knowledge measurement of its human component. Additional research should be conducted on technology-enablers of real time-visibility and connectivity that permit ad hoc performance measurement. Supply chain data warehousing and on line interactive databases should be further investigated to maximize inquiring and to minimize measurement reporting.

There is need to fill the gaps by adequately defining, measuring, improving supply chain activities; focusing on multi-firm and inter-firm supply chain measurement; balanced weightage to internal efficiency and external effectiveness; making interdependent planning and governance structure to appear across the supply chain; synchronizing activities of various supply chain members with broad-interest focus; developing methods to remove vertical conflicts by proper system of joint planning and measurement and evaluating consequences of firm performance as well as the impact of those outcomes on the various members of supply chain.

To summarize these research gaps, a brief account of these gaps, as addressed by prominent authors is given below:

- "Supply chain metrics should measure inter-company performance rather than just internal performance. These measures of performance must be common across the firms in the supply chain to be meaningful". (Fisher, 1997)
- "There is little attention to the performance evaluation of supply chain and its metrics" (Gunasekaran, Patel & Tirtiroglu, 2001 and Lee & Billington,1992)
- "There is lack of a balanced approach in SCM performance measures". (Gunasekaran et al., 2001)
- "Most studies so far have suggested one standard scm performance measure without considering the company's situation. Need is their to integrate them to encompass all possible perspectives, such as adaptability, holistic vision, strategic linkaging, critical success measures and their impact strength… "(Beamon,1999, Brewer & Speh, 2000, Gunasekaran et al., 2001, and Lapide, 2002)

The Balanced scorecard to measure supply chain performance (Brewer & Speh, 2000) thus provides the base for developing an integrated multi-perspective framework in which measures are arranged in a strategic linkaging mode. The present work will attempt to use structural modeling to establish the causality among measures, so that they can be differentiated according to their dependency and independency. Thus the above account of identified research gaps justifies the need of developing an integrated multi-perspective framework in SCPM.

Chapter – 3

Proposed Integrated BSCS Framework for Supply Chain Performance Measurement:

Perspectives, Dimensions and Measures

Traditionally, companies have tracked performance based largely on financial accounting principles, many which date back to the ancient Egyptians and Phoenicians. Financial accounting measures are certainly important in assessing whether or not operational changes are improving the financial health of an enterprise, but insufficient to measure supply chain performance for the following reasons:

- The measures tend to be historically oriented and not focused on providing a forward- looking perspective.
- The measures do not relate to important strategic, non-financial performance, like customer service/loyalty and product quality.
- The measures do not directly tie to operational effectiveness and efficiency.

3.1 Developing an Effective Performance Measurement Framework

“You are what you measure” (Hauser & Katz, 1998). The central role of performance measurement in managing an organization to achieve its desired performance goals has long been recognized from the days of management accounting. The changing landscape of the competitive environment in last two decades has compelled organizations to excel beyond mere financial performance, looking for improvements also in quality, speed, flexibility, etc. Consequently, the ways and means of accurately measuring performance became an increasingly important field of research for both organizations and academia.

Extensive efforts have been carried out to define and further enhance performance measurement practices across various components of the organization and then integrate them across the organization in a performance measurement system. This chapter provides a detailed understanding of the various aspects of performance measurement as well as a review of select performance measurement frameworks that have been widely adopted to facilitate the design of a performance measurement system. It concludes with discussion on some limitations of these performance measurement frameworks.

3.1.1 Performance Measures

A performance measure is a verifiable variable that is expressed in either quantitative or qualitative terms. Neely and Gregory (1995) define performance measure as a variable used to quantify the efficiency and effectiveness of an action. Daum (2004) extends the definition of performance measure to include qualitative aspect because different stakeholders put different value on the same outcome, which cannot be quantified. Also, intangible measures to a large extent cannot be quantified, and thus require qualitative measures (Lev, 2001). Performance measures capture characteristics or outcomes in a numerical or a nominal form (Ghalayini et al., 1997).

A performance measure should be based on an agreed upon set of data and a well understood and well documented process for converting that data into the measure. Given the data and process, independent sources should be able to arrive at the same measure value (Melnyk et al., 2004). To interpret meaning from a measure, however, it must be compared to a target.

Targets should be clearly stated for each performance measure and should provide a challenge to employees to achieve high performance levels. (Box and White, 1993) have suggested using statistically derived performance targets, while Spendolini (1992) suggests using standardized benchmark performance targets. Sinclair and Zairi (2000) have noted that the target is designed to be a path of improvement rather than comparing performance with a static target. Several authors, notably Miller (1990) and Maskell (1991) suggest graphing performance against improvement targets, both to highlight historical trends and to foster awareness for continuous improvement. Schneiderman (1988) suggested plotting targets using the 'half life' concept, to keep continuous improvement process on track.

Performance measures also should be designed considering the action(s) and behaviors that they will drive. Eccles and Pyburn (1992) identified in their research that the impact of performance measure of one activity may not be limited to just that activity. Also, performance measures have behavioral impact, especially in systems involving humans who respond to performance measures (Neely et al., 1997). People modify their behavior and actions to ensure positive performance even if this means inappropriate course of action (Kerr, 2003).

A performance measure will lead to an effective performance measurement and ultimately performance improvement if it is systematically designed to address all the elements. Nelly et al. (1997) note the following:

> *"….a plant where the performance of a plant manager was assessed on the basis of return on investment; the performance of a product group manager was assessed on the basis of whether or not product was delivered on time and performance of the shop-floor supervisor or operator was assessed on the basis of production output versus standard. The measures induced dysfunctional behavior in the system."*

In a manufacturing environment there are several ways in which production output can be increased. One option is to reduce cycle times, either through product or process innovation. Another is to eliminate the causes of unproductive time, perhaps through the introduction of a preventive maintenance program, which reduces the risk of machine breakdowns. A third is to seek to eliminate the time wasted in producing poor quality product possibly through the introduction of fail safe, or *poka yoke* devices. In this particular plant the shop floor supervisors and operators decided to try and reduce unproductive time by decreasing the amount of time spent on set-ups. Rather than implementing a setup time reduction program, however, they decided simply to eliminate the need to set-up machines as frequently by increasing batch sizes. Thus they could meet the desired standard output. Increased batch sizes led them to produce more of non required product leaving product managers without necessary product to fulfill the particular orders. They responded sanctioning overtimes, which once again adversely affected return on investment. Thus, the design of a performance measure should involve various elements that can improve the quality of metrics, communicate appropriate information and lead the behavior and action towards overall goal.

Hence the design of performance measures should be comprehensive enough to capture all the attributes that will enable the performance measurement process to successfully carry out the desired roles. A comprehensive design of the performance measure requires an understanding of all the elements that can affect performance measurement, as well as potential subsequent actions, including the dimensions and levels of measurement.

3.1.2 Elements of Performance Measures

Various authors have discussed one or more elements of design of performance measures in the organizational context. Neely et al. (1997), through their comprehensive literature review and study of these elements, have proposed a template for a detailed design of the performance measures, which they call the "performance measure record sheet". It includes ten different elements that contribute to the design of a robust performance measure. In addition, others have attempted to include the process and world-class manufacturing views in designing performance measures. To manage performance by processes, it is measured across the process as well at the individual task level (Toni & Tonchia, 1996). Thus, the scope of performance measure should play a part in the design of performance measures. Also, the performance measure should be owned by the responsible individual task or process owner (Hammer & Champy, 1993). Lohman et al. (2004) modified the performance record sheet to involve the process elements to design the measures across the supply chain process.

- ***Title:*** The title of the measure should be clear. A good title is one that explains what the measure is and why it is important. It should be self-explanatory and not include functionally specific jargon.

- ***Purpose:*** If a measure has no purpose then one can question whether it should be introduced. Hence the rationale underlying the measure has to be specified.

- ***Relates to:*** The business objectives to which the measure relates should be identified.

- ***Target:*** The objectives of any business are a function of the requirements of its stakeholders. An appropriate target for each measure should therefore be recorded based on the trade offs between the stakeholder requirements.

- ***Formula:*** It is the way performance is measured and affects how people behave.

- ***Frequency:*** The frequency with which performance should be recorded and reported is a function of the importance of the measure and the volume of data available.

- ***Who measures:*** The person who is to collect and report the data should be identified?
- ***Source of data:*** The source of the raw data should be specified. The importance of this question lies in the fact that a consistent source of data is vital if performance is to be compared over time.
- ***Who acts on the data:*** The person who is to act on the data should be identified?
- ***What do they do:*** This is probably the most important element contained on the performance measure record sheet, not because it contains the most important information, but because it makes explicit the fact that unless the management loop is closed, there is no point in having the measure.

3.1.3 Characteristics of Performance Measures

While choosing performance measures managers need to be aware of the complexity in the variety of measures. Performance measures can be broadly classified cross three characteristics (Figure 3.1). The first characteristic is 'measure type', which includes both financial and non-financial measures. Johnson and Kaplan (1987) underscored the need for inclusion of non-financial measures because traditional accounting/financial measures ignore clients and internal operational needs. Based on similar logic, McNair and Mosconi (1987) called for the alignment of financial and non-financial measures to be in accordance with business strategy. Santori and Anderson, (1987) stressed the importance of non-financial measures in monitoring and motivating the progress of the human factor of the organization. Maskell (1991) suggests that in a world-class manufacturing environment performance is primarily measured using non-financial measures. Financial measures define pertinent elements in terms of a monetary resource equivalent, whereas non-financial measure tends to define operational as well as qualitative measures, such as employee moral, customer relationships, etc.

The second characteristic is 'tense', that is, a leading versus lagging indicator, which depends on how a measurement is intended to be used (Higgins & Hack, 2004). Measures can be used both to judge outcomes as well as predict the future. Lagging indicators are important to show actual outcomes, while leading indicators are vital because they can be used to glean information, guide decision making and assess likelihood for success (Ittner & Larcker, 1997). Leading indicators serve as timely reference points that influence short- and long-term strategy. They allow the organization to take pre-emptive action to resolve issues that may be hindering progress towards a goal (Kaplan & Norton, 2001). For example, revenue and net earnings are lagging indicators, yet customer satisfaction is a leading indicator of revenue.

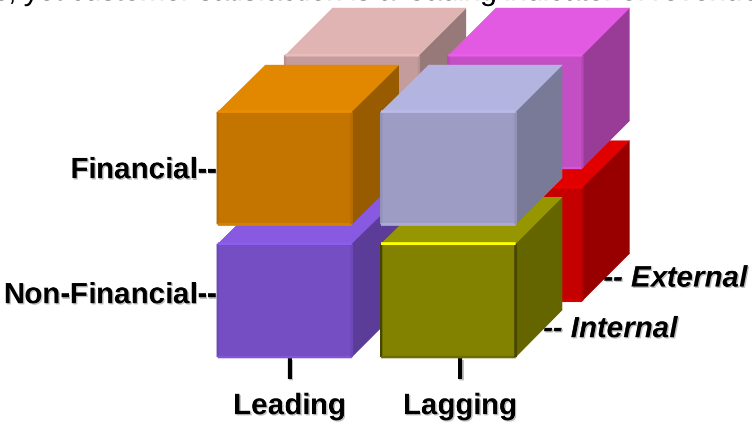

Figure 3.1: Characteristics of Performance Measurement

The third characteristic is 'focus', that is, internal versus external. It is critical to measure a firm's internal performance against targets set, based on stakeholder expectations (Crowther, 1996). It is also equally important to measure external performance to set benchmarks and satisfy some of the external stakeholders and maintain competitive positions (Basu & Wright, 1996). Dumond (1994) explains two contextual measures, an internal one –organizational performance and health – and an external one – the market within which the organization competes and events that impact performance. Bullinger et al. (2002) take a supply chain perspective and explain that large-scale networks are characterized by a high internal and external dynamic. The (internal) structure of the network changes rapidly, new partners have to be integrated, others have to be excluded, depending on customer orders, productivity, etc. In addition, the network is permanently subject to (external) changes of business environment (e.g. market demand, competitors).

Thus for this research, in which an integrated multi-perspective framework is ought to be developed by identifying measures, the measurement focus must be clearly shown. Organization performance may be viewed internally or externally. The perspective to which manager wants to give more attention should be reflected by this "focus" characteristic of performance measures. The "tense" characteristic of performance measure is the base for developing a structural model, where causality plays a significant role. The leading indicators have more influencing power and they are extremely important for effective managerial decision making. The "type" characteristic of measures in the context of this research will be expanded to cover all four perspectives of Balanced Score Card (BSC), in which three perspectives are of non-financial type. For a balanced view of organizational performance status it should excel in both financial and non-financial measures.

These three characteristics are extremely important while selecting supply chain performance measures. The attempt to classify measures in different perspectives of BSC has taken care of this fact in section 3.4.

3.1.4 Levels of Performance Measurement System

Good measures are indices made up of several measures across different levels in an organization (Higgins & Hack, 2004). Neely and Gregory (1995b) suggests two levels of measures: individual measures and a performance measurement system that aggregates all of them. Other researchers (e.g., Johnston et al., 2002, Melnyk et al., 2004 and Lohman et al., 2004) suggest performance measures can be categorized in hierarchical fashion across three levels of aggregation to achieve overall optimal performance.

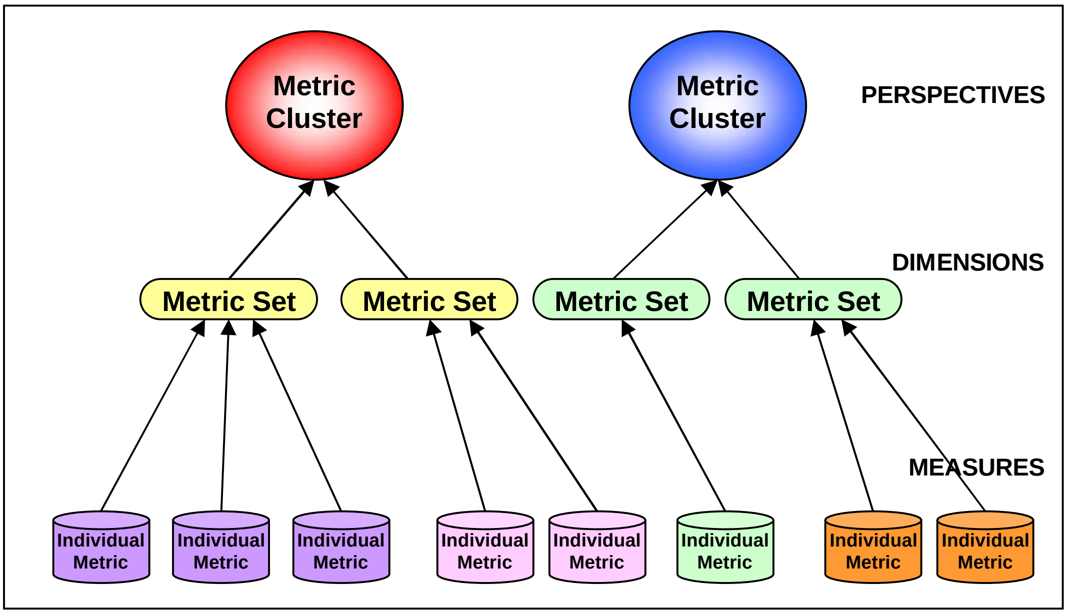

Figure 3.2: Levels of Performance Measurement System (Lohman, 2004).

These three levels of performance measurement system are linked with each other (Figure 3.2). At the base is the 'individual metric', the building block. Individual metrics are aggregated to form various 'metrics sets'. Each set directs, guides, and regulates an individual's activities in support of strategic objectives. And the top level is the 'metric cluster', which aggregates the individual metric and metric set in a fashion to link with strategy and stakeholder values (Brignall, 2003 and Lohman, 2004).

Metric clusters are derived from stakeholder values and prioritized strategic choices. The metrics set consists of measures assigned by a strategic level to direct, motivate and evaluate performance of a specific activity, process, area, or function. The metrics set is critical because it is often a leading indicator, and because the scope and complexity of an individual's set can be viewed as a load imposed on a manager's finite mental capacity. Coordinating and managing the development of the various individual metrics, metrics sets and metric cluster is the performance measurement system.

In the supply chain context the metric clusters can be termed as the **Perspectives**, and the metric set in each perspective is termed as **Dimension**. These Dimensions are having their own individual metric which are basically the building blocks of the performance measurement system and termed as **Measures**. To illustrate the same an example is given below:

> *Organizations in a supply chain generally face the problem of bullwhip effect which adversely affects the efficiency of entire supply chain. The reason behind this bullwhip effect is mainly the demand uncertainty and the lack of trust between members of the chain. These two issues can be resolved if members of supply chain make efforts to improve their relationships with partners and to improve information flows. As a whole these two improvement efforts are the part of their performance enhancement initiative in Innovation and Learning perspective. To improve information flow among supply chain members, they should focus on quantitative measure, like Number of shared data sets / total data sets, % of customer sharing forecast, % of supplier sharing forecast. For improving partnership management qualitative measure like Trust with customer, Trust with supplier or quantitative measures like VMI (Vendor Managed Inventory) & CRP (Continuous Replenishment Program) ratio should be analyzed.*
>
> *In this example if performance measurement system levels are identified, then Innovation and Learning is the **Perspective** (metric cluster), Information Flows and Partnership Management are two broad categories in this perspective and termed as **Dimensions** (metric set). All the qualitative and quantitative indicators like number of shared data sets / total data sets… and trust with customer…are **Measures** (individual metric) in respective dimensions (metric sets).*

Thus a performance measurement system is consisting of various perspectives. Each perspective can be further divided into dimensions. These dimensions are broad category of various performance measures to whom they represent in broad sense. So each dimension is having many measures.

The performance measurement system is ultimately responsible for maintaining alignment and coordination. Alignment deals with the maintenance of consistency between the strategic goals and measures as plans are implemented and restated as they move from the strategic through tactical and operational stages of the planning process. Alignment attempts to ensure that at every stage objectives set at higher levels are consistent with and supported by measures and activities at lower levels. In contrast, coordination recognizes the presence of interdependency between processes, activities or functions. It deals with the degree to which the measures in various related areas are consistent with and supportive of each other. Coordination strives to reduce potential conflicts that can occur when one area focuses on maximizing uptime (for example, by avoiding setup and running large batches) and another focuses on quality and flexibility. Coordination tries to maintain an equivalence of activities, goals, and purpose across departments, groups, activities and processes.

Measures need to be part of an integrated system that integrates the goals of everyone in the organization, such that they all work together for the benefit of the organization as a whole (Sinclair & Zairi, 2000). Architecting a performance measurement system considering roles, elements, characteristics, and levels require a systematic structure and a process.

3.1.5 Performance Measurement Frameworks

Performance measurement frameworks have arguably made the largest impact upon the performance measurement literature, with a plethora of ever more complex ones having been developed since the late 1980s, addressing one or more dimensions, levels and/or roles of performance measurement (Ghalayini et al., 1997). Most performance measurement systems developed in organizations are a collection of best practices that have been grafted onto various performance measurement frameworks, and have been found to work anywhere between very well and very badly (Johnston et al., 2002). Eccles (1991) postulated that a performance measurement framework provides the structure and procedure to execute performance measures in a consistent and complete way.

The basic requirements for a successful performance measurement system are frameworks with two aspects: structure and procedure. Generally, they also have a number of other tools and techniques, such as statistical process control, etc. (Bititci et al., 1997, Kennerley & Neely, 2003a and Folan & Browne, 2005). Performance measurement frameworks assists in the process of performance measurement system building by clarifying performance measurement boundaries, specifying performance measurement dimensions or focus, and may also provide initial intuitions into relationships among performance measurement dimensions. Performance measurement frameworks can be classified based on two aspects (Folan & Browne, 2005):

- ***The structural framework*** - A framework specifying a typology for performance measure management

- ***The procedural framework*** - A step-by-step process for developing performance measures from strategy and a systematic process to manage the evolution of a performance measurement system.

Several authors have researched and presented different aspects of, as well as the entire performance measurement framework (Ghaylani 1997 and Johnston, 2003). Performance measurement framework design based on structural framework development has considerably outstripped the pace of procedural performance measurement framework development. Structures presented by researchers and practitioners have evolved to address drawbacks from previous frameworks and to better serve the organization to deploy novel operational strategies.

This section presents a review of selected eminent performance measurement frameworks, some of which have been widely adapted by the industry. The frameworks are reviewed and presented roughly in the sequence of their evolution, which includes:

- Strategic Measurement and Reporting Technique

- Balanced Scorecard and Strategy Maps

- Performance Prism

These three frameworks capture primarily structural elements. Dixon (1990) identified that performance measures should change with the change in the business environment. Very few procedural frameworks have been proposed that describe systematic procedure to develop and maintain the performance measurement system.

3.1.6 Strategic Measurement and Reporting Technique (SMART)

In response to the dissatisfaction with traditional performance measures and management accounting systems, Wang Laboratories, Inc. developed a new approach to measurement -- the Strategic Measurement and Reporting Technique (SMART) (Cross & Lynch, 1988). SMART aims to integrate financial and non-financial reporting, link operational performance measures to strategic goals, focus the measurement system on satisfying customer needs and ultimately on achieving corporate goals. The SMART hierarchy (or 'performance pyramid') is shown in Figure 3.3. At the top of the pyramid are the corporate vision, which defines the markets the company competes in, product scope and services provided. The vision leads to strategic goals for the marketplace (market share, etc.) and detailed financial goals. These goals are called strategic business objectives, and lead to business operating system objectives of customer satisfaction, flexibility and productivity. To meet these objectives, people must work across functional boundaries and business units. The last level in the hierarchy is departmental and work centre criteria, including quality, delivery, process time, and waste. Waste is the only category that includes cost. For each goal, objective, and criterion, SMART needs at least one measure. It also recognizes that measures are imperfect, and will be improved over time to serve future requirements of customers better.

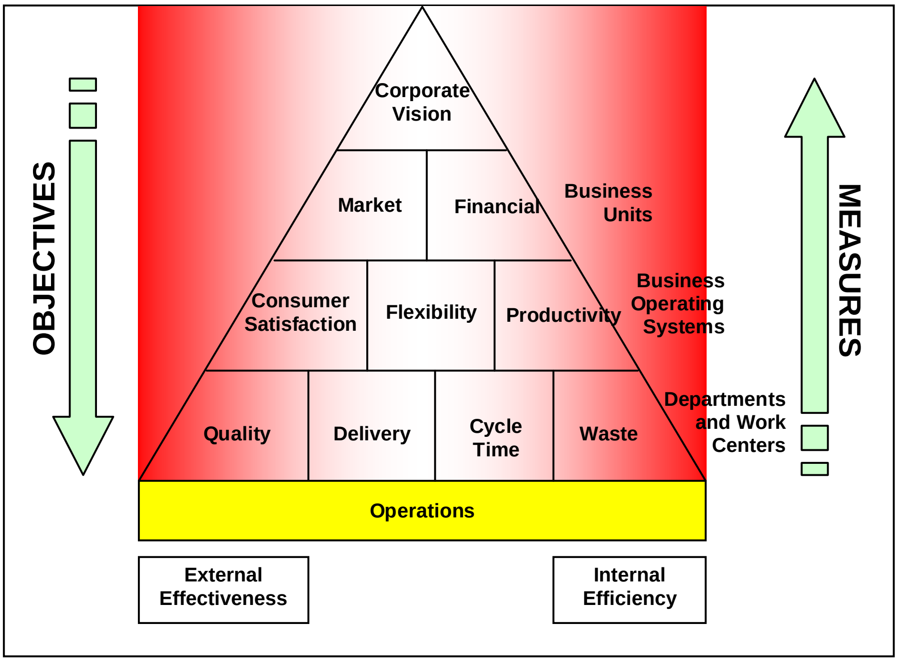

Figure 3.3: The Performance Pyramid (Cross & Lynch, 1988)

3.1.7 The Balanced Scorecard and Strategy Maps

Schineiderman (1988) invented the Balanced Scorecard at Analog Devices. It was further refined and publicized by Kaplan and Norton (1992). The Balanced Scorecard provides a high-level structure to integrate strategic goals with financial and non-financial measures. Goals are set by managers with regard to four perspectives:

- Financial perspective: How do we look to our shareholders?
- Internal business perspective: What must we excel at?
- Customer perspective: How do our customers see us?

- Innovation and learning perspective: How can we continue to improve and create value?

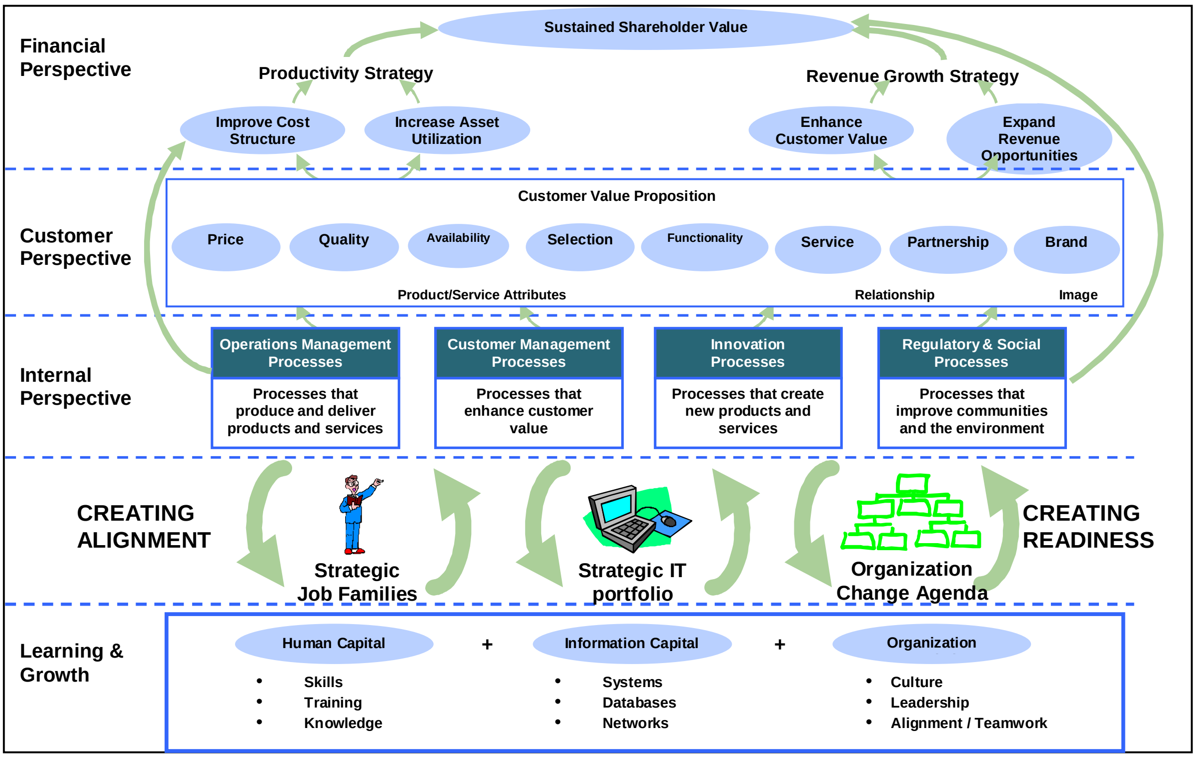

Figure 3.4: Strategy Map (Kaplan & Norton, 2000)

In 1996 Kaplan and Norton provided an additional procedural framework through which the scorecard can be applied as a system—thus managing the firm's strategy. The framework is in four stages:

- ***Translating the vision*** is concerned with clarifying and gaining consensus over a version of the firm's strategic vision that is operational upon all levels of the organization (i.e., from the top level down to the local level).

- ***Communicating and linking*** is the process by which managers communicate their strategy up and down the organization and link it to departmental and individual objectives.

- ***Business planning*** is the process by which companies integrate their business and financial plans.

- ***Feedback and learning*** gives companies the capacity for strategic learning; existing processes review whether individual and departmental financial goals have been achieved, while the Balanced Scorecard enables a company to monitor short-term results for its three additional perspectives.

Strategy maps (Kaplan & Norton, 2000) are a natural extension to balanced scorecards. Although the strategy map follows the logic of the scorecard, it offers a different visualization of the four scorecard perspectives. In this way it reflects the assumed causal relationships between the goals and measures on the scorecard (Figure 3.4). Although strategy maps are relatively easy to produce, they can be constraining if they are bound too closely to the four balanced scorecard perspectives. Most organizations today are more complex than the four perspectives included in the scorecard and executives are required to address the needs of stakeholders other than just customers and shareholders.

3.1.8 The Performance Prism

To overcome the shortcomings in the Balanced Scorecard approach, the Performance Prism was developed (Neely & Adams, 2001). The Performance Prism (Figure 3.5) is based on the belief that organizations aspiring to be successful in the long term in today's business environment have an exceptionally clear picture of who their key stakeholders are and what they want. They have defined what strategies they will pursue to ensure that value is delivered to these stakeholders.

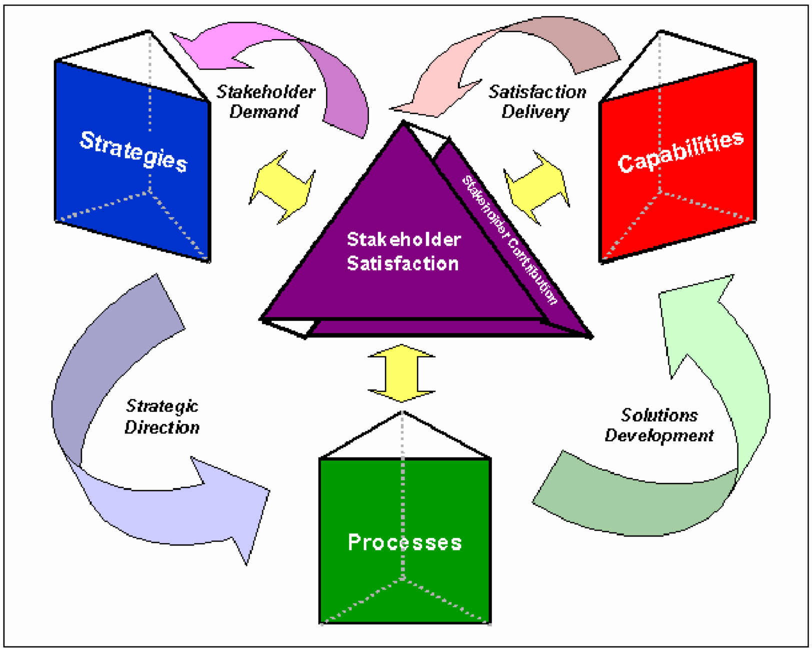

Figure 3.5: The Performance Prism (Neely & Adams, 2001)

They understand what processes the enterprise requires if these strategies are to be delivered and they have defined what capabilities they need to execute these processes. The most sophisticated of them have also thought carefully about what it is that the organization wants from its stakeholders – employee loyalty, customer profitability, long-term investments, etc. In essence, they have a clear business model and an explicit understanding of what constitutes and drives good performance.

The Performance Prism takes a broader view of stakeholders and encourages organizations to address the following questions:

- Who are our key stakeholders and what do they want and need?
- What strategies do we have to put in place to satisfy these needs?
- What process do we need to have in place to execute our strategy?
- Which capabilities do we need to perform our processes?
- What do we expect from our stakeholders in return?

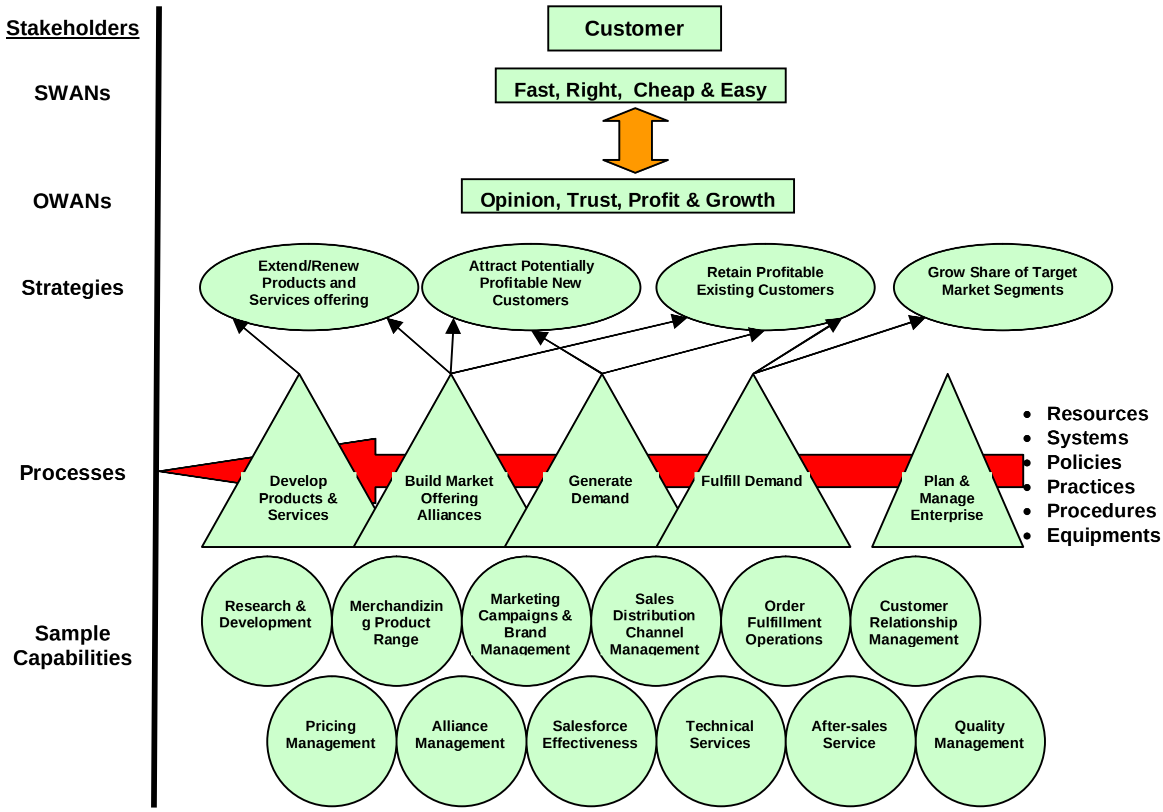

Figure 3.6: Customer Success Map Example (Neely et al., 2002)

Addressing these five questions allows organizations to build comprehensive success maps, sometimes by each major stakeholder (see Figure 3.6 for an example of a customer success map, Neely et al., 2002). A further refinement suggested by Neely et al., (2002) is the notion of failure or risk maps. These identify potentially critical failure points in an organization that if unmonitored could lead to excess exposure to risk. The broader stance adopted by the Performance Prism and its reliance on success and failure maps provides a flexible structure that enables organizations to map everything that is important to them in their success and failure maps.

3.2 Supply Chain Performance Measurement Models: Overview

Over the years the Supply Chain Management concept has undergone many changes and so its performance measurement as well. At least five distinct management stages can be identified in evolution of SCM. The first can be described as the era of internal logistics departmentalism. In the second stage, logistics began the migration from organizational decentralization to centralizations of core functions driven by new attitudes associated with cost optimization and customer service. Stage three witnessed the dramatic expansion of logistics beyond a narrow concern with internal warehousing and transportation to embrace new concepts calling for the linkage of internal operations with analogous functions performed by channel trading partners. As the concept of channel relationships grew, the old logistics concept gave away, in stage four, to full supply chain management. Today with the application of Internet technology to the SCM concept, it is emerging into stage five, e-SCM. With these changing stages of SCM the management focus towards their performance also change over years. A short discussion of changing management focus towards SCM performance improvement initiatives in each stage is as follows:

Table 3.1: Stages of SCM Focus of Performance Measurement Initiatives (Ross, 2003)

	SCM Stage	Management Focus of Performance Improvement Initiatives
Stage 1 1900-1960	**Warehousing and Transportation**	Operations Performance Support for Sales / Marketing Inventory Control Transportation efficiency
Stage 2 1960-1980	**Total Cost Management**	Logistics Centralization Total Cost Management Optimizing Operations Customer Service Logistics as a Competitive Advantage
Stage 3 1980-1990	**Integrated Logistics Management**	Logistics Planning Supply Chain Strategies Integration with Enterprise Functions / Channel Operations Functions Support for TQM
Stage 4 1990-2000	**Supply Chain Management**	Strategic View of Supply Chain Use of Extranet Technologies Growth of Coevolutionary Channel Alliances Collaboration to Leverage Channel Competencies Benchmarking Re-engineering
Stage 5 2000+	**e-Supply Chain Management**	Application of Internet to SCM Concept Low-Cost Instantaneous sharing of all Databases e-Information, SCM Synchronization Organizational Agility and Scalability Networked Multi-Enterprise Supply Chain

In response to these changing management focuses in measuring supply chain performance, a variety of measurement approaches have been developed, including the following:

- Cash Velocity
- The Balanced Scorecard
- The SCOR Model
- The Logistics Scoreboard
- Activity-Based Costing (ABC)
- Economic Value Analysis (EVA)
- Other Frameworks

3.2.1 Cash Velocity

The ability to cycle assets and cash to generate growth » directly dependent on how quickly value can be passed through the supply channel. Cash velocity in the supply chain is best considered as a component of value, rather than the value itself, and is affected by inventory turnover, transaction costs, current liabilities turnover, growth rate net profit margin, and the tax rate. Where assets build at various points in the supply network, cash turns to cost No better example can be seen than in the high-tech sector, where companies like Dell face short product life cycles that require rapid flow-through of assets from suppliers, to outsourced manufacturers, to the customer, measured in days. Optimizing cash velocity requires aligning supply network partner processes and resources with channel customers, products, and services to achieve the quickest return. Models to deploy to increase cash velocity include optimal asset utilization (OAD), activity based costing (ABC), event-driven costing, and cash velocity levers, such as receivable and inventory turnover.

3.2.2 The Balanced Scorecard

The Balanced Scorecard recommends the use of executive information systems (EIS) that track a limited number of balanced metrics that are closely aligned to strategic objectives. The approach was initially developed by Robert S. Kaplan and David P. Norton and was discussed in an article, titled “The Balanced Scorecard: Measures that Drive Performance,” published in the Harvard Business Review, January-February 1992.

While not specifically developed for supply chain performance measurement, Balanced Scorecard principles provide excellent guidance to follow when doing it. The approach would recommend that a small number of balanced supply chain measures be tracked based on four perspectives:

- Financial perspective (e.g., cost of manufacturing and cost of warehousing)
- Customer perspective (e.g., on-time delivery and order fill rate)
- Internal business perspective (e.g., manufacturing adherence-to-plan and forecast errors)
- Innovative and learning perspective (e.g., APICS-certified employees and new product development cycle time)

An industry has grown around the Balanced Scorecard approach with a variety of firms that provide consulting and solutions for implementing performance measurement, such as:

- Renaissance Worldwide, Inc. (Newton, MA) got its start doing this Balanced Scorecard consulting and grew to be one of the 30 largest consulting firms
- Gentia Software Inc. (Boston, MA) markets a software application, Gentia's Renaissance Balanced Scorecard that incorporates Renaissance Worldwide's performance measurement approach.
- Corvu Corp. (Edina, MI) sells a Balanced Scorecard System software application that provides interactive scorecard functionality.

3.2.3 The SCOR Model

The Supply Chain Council's (SCC) Supply-Chain Operations Reference (SCOR) model provides guidance on the types of metrics one might use to get a balanced approach towards measuring the performance of one's overall supply chain.

The SCOR Model approach advocates a set of supply chain performance measures comprised of a combination of:

- Cycle time metrics (e.g., production cycle time and cash-to-cash cycle)
- Cost metrics (e.g., cost per shipment and cost per warehouse pick)

- Service/quality metrics (on-time shipments and defective products)
- Asset metrics (e.g., inventories)

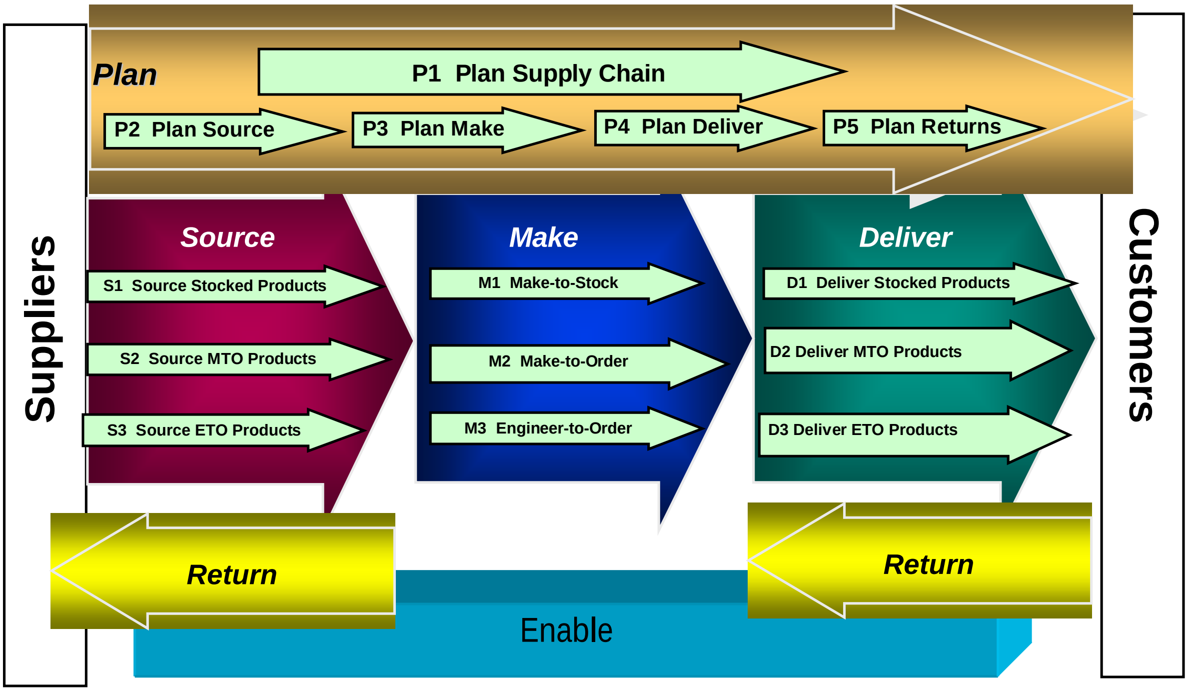

Figure 3.7: SCOR Model (SCC, 2004)

In contrast to the Balanced Scorecard, which is focused on executive enterprise-level measurement, the SCOR Model approach directly addresses the needs of supply chain management with balanced measurements. Figure 3.7 depicts an illustrative set of supply chain measures balanced among the SCOR Model's top-level processes.

Supply Chain Operations Reference (SCOR) model, integrates the well-known concepts of business process reengineering, benchmarking, and process measurement into a cross-functional framework. SCOR contains:

- Standard descriptions of management processes
- A framework of relationships among the standard processes
- Standard metrics to measure process performance
- Management practices that produce best-in-class performance
- Standard alignment to features and functionality

Figure 3.8 illustrates the SCOR model's three-level structure. The system is not ideal for all supply chains, however. Dutta [2004] described some of its present limitations, explicitly excluding sales and marketing (demand generation), research and technology development, product development and some elements of post-delivery customer support. All of these have some impact and influence on supply chains.

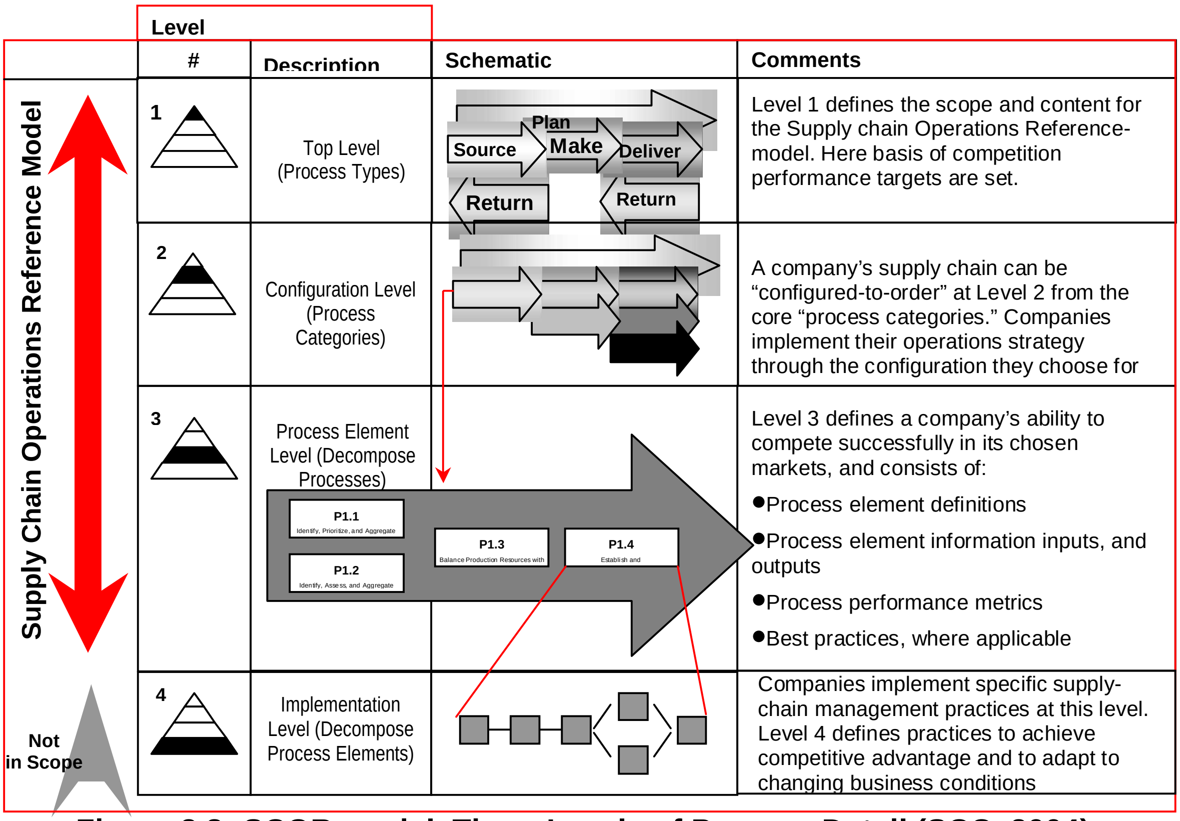

Figure 3.8: SCOR model, Three Levels of Process Detail (SCC, 2004)

3.2.4 The Logistics Scoreboard

Another approach to measuring supply chain performance was developed by Logistics Resources International Inc. (Atlanta, GA), a consulting firm specializing primarily in the logistical (i.e., warehousing and transportation) aspects of a supply chain. The company recommends the use of an integrated set of performance measures falling into the following general categories:

- Logistics financial performance measures (e.g., expenses and return on assets)
- Logistics productivity measures (e.g., orders shipped per hour and transport container utilization)
- Logistics quality measures (e.g., inventory accuracy and shipment damage)

- Logistics cycle time measures (e.g., in transit time and order entry time)

Logistics Resources sells a spreadsheet-based, educational tool called The Logistics Scoreboard that companies can use to pilot their supply chain performance measurement processes and to customize for ongoing use. The tool and a monograph (Logistics Performance, Cost, and Value Measures that documents the tool and its use) are distributed by The Penton Institute (Cleveland, OH). In contrast to the other approaches discussed, The Logistics Scoreboard is prescriptive and actually recommends the use of a specific set of supply chain performance measures. These measures, however, are skewed toward logistics, having limited focus on measuring the production and procurement activities within a supply chain.

3.2.5 Activity Based Costing

The Activity-Based Costing (ABC) approach was developed to overcome some of the shortcomings of traditional accounting methods in tying financial measures to operational performance. The method involves breaking down activities into individual tasks or cost drivers, while estimating the resources (i.e., time and costs) needed for each one. Costs are then allocated based on these cost drivers rather than on traditional cost-accounting methods, such as allocating overhead either equally or based on less-relevant cost drivers. This approach allows one to better assess the true productivity and costs of a supply chain process. For example, use of the ABC method can allow companies to more accurately assess the total cost of servicing a specific customer or the cost of marketing a specific product. ABC analysis does not replace traditional financial accounting, but provides a better understanding of supply chain performance by looking at the same numbers in a different way. ABC methods are useful in conjunction with the measurement approaches already discussed as their use allows one to more accurately measure supply chain process/task productivity and costs by aligning the metrics closer to actual labor, material, and equipment usage.

3.1.6 Economic Value-Added

One of the criticisms of traditional accounting is that it focuses on short-term financial results like profits and revenues, providing little insight into the success of an enterprise towards generating long term value to its shareholders – thus, relatively unrelated to the long-term prosperity of a company. For example, a company can report many profitable quarters, while simultaneously disenfranchising its customer base by not applying adequate resources towards product quality or new product innovation. To correct this deficiency in traditional methods, some financial analysts advocate estimating a company's return on capital or economic value-added. These are based on the premise that shareholder value is increased when a company earns more than its cost of capital. One such measure, EVA, developed by Stern, Stewart & Co., attempts to quantify value created by an enterprise, basing it on operating profits in excess of capital employed (through debt and equity financing). Some companies are starting to use measures like EVA within their executive evaluations. Similarly, these types of metrics can be used to measure an enterprise's value added contributions within a supply chain. However, while useful for assessing higher level executive contributions and long term shareholder value, economic-value added metrics are less useful for measuring detailed supply chain performance. They can be used, however, as the supply chain metrics within an executive-level performance scorecard, and can be included in the measures recommended as part of the Logistics Scoreboard approach.

3.1.7 Other Frameworks

A number of performance measurement frameworks and related metrics have been proposed. Beamon (1998) classified performance metrics into two categories; qualitative metrics for which there is no single direct numerical measurement, and quantitative metrics that may be directly described numerically. Qualitative measures include customer satisfaction, flexibility, information and material flow integration, effective risk management and supplier performance. Quantitative measures include measures based on cost and measures based on customer responsiveness. This author also developed a new framework for performance measurement. Within this framework, a supply chain performance measurement system that consists of a single performance measure is generally inadequate, since it is not inclusive and ignores the interactions among important supply chain characteristics. Key strategic elements in the organization include the measurement of resources, output and flexibility. Therefore, as shown in Figure 3.9, a supply chain measurement system must put emphasis on three separate types of performance measures: resource measures (R), output measures (O) and flexibility measures (F). Each of the three types of measures has important characteristics and interacts with others.

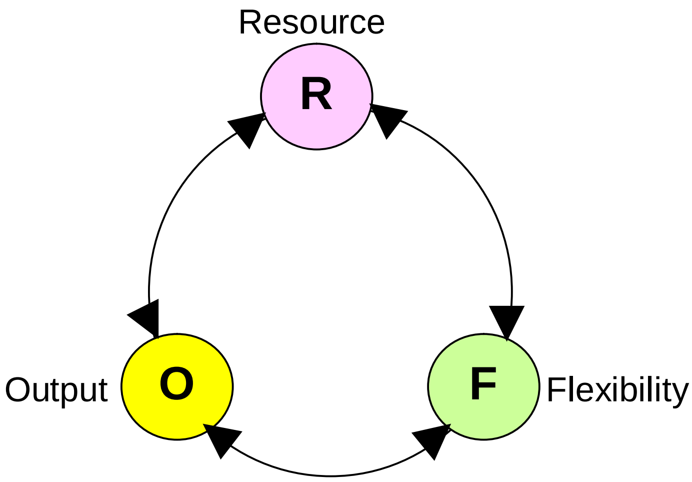

Figure 3.9: The Supply Chain Measurement System (Beamon, 1999)

Beamon believed that an effective supply chain performance measurement system must contain at least one individual measure from each of the three identified types shown in Table 3.1.

Table 3.2: Goal of Performance Measure Types (Beamon, 1999)

Performance Measure Type	Goal	Purpose
Resources	High level of Efficiency	Efficient resource management is critical to profitability.
Output	High level of Customer Service	Without acceptable output, customers will turn to other supply chains
Flexibility	Ability to Respond to a Changing Environment	In an uncertain environment, supply chains must be able to respond to change.

Gunasekaran et al. (2001) classified performance metrics into four groups along the four links of an integrated supply chain, named as follows: plan, source, make/assemble and delivery/customer. Measures for plan include the order entry method, order lead-time and the customer order path. Measures for source include supply chain partnership and related metrics such as the level of information sharing and buyer-vendor cost saving initiative. Measures for make/assemble include the range of products and services, capacity utilization and effectiveness of scheduling techniques. Lastly, measures for delivery/customer include measures for delivery performance evaluation such as on-time delivery, and measures for total distribution cost. A final class of metric addressing customer satisfaction was added. The framework is illustrated in Figure 3.10.

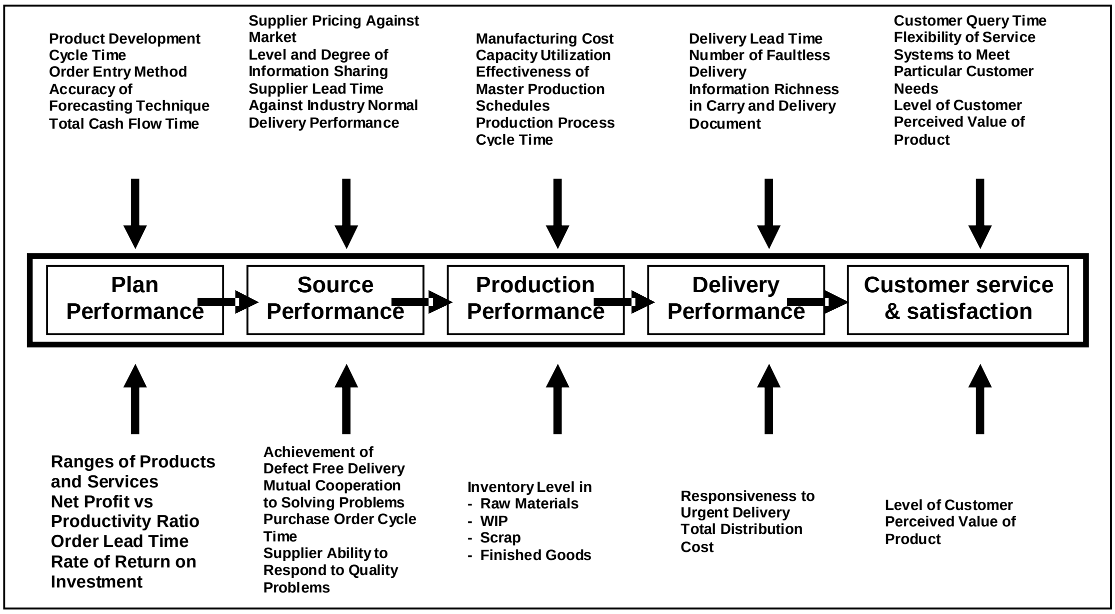

Figure 3.10: Metrics at 5 Basic Links in a Supply Chain (Gunasekaran et al., 2001)

Gunasekaran et al. (2004) extended this framework to include a temporal dimension. Metrics for each of the four processes were further divided into strategic, tactical and operational metrics.

Hausman (2003) emphasized that businesses need to migrate from single-dimensional measures to multi-dimensional ones and from a single-enterprise focus to a cross-enterprise focus. He identified that Supply Chains need to perform on three key dimensions: Service, Assets and Speed. (Figure 3.11)

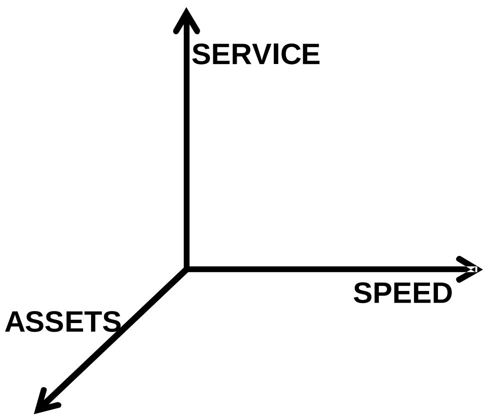

Figure 3.11: Dimensions of Performance Metrics of Supply Chains (Hausman, 2003)

Hausman also stressed that businesses using multi-dimensional performance measures should recognize that not all dimensions are equally important, and some tradeoffs are necessary. Understanding tradeoffs and as a result, knowing how to set priorities and targets is crucial. An example of an important tradeoff is the balance between inventory level and customer service.

Chan and Qi (2003) developed a performance measurement framework for the supply chain with a process-based approach, as Figure 3.12 shows. In this model, a process in the supply chain is a series of activities from original suppliers and manufactures, through to retailers, which add value for the end customers, each performing a specific set of functions. The performance of each process is the aggregated results of the performance of all preceding activities. Therefore, assessing the performance of activities can depict the effect of corresponding processes. Based on the model, the authors proposed a 'metrics board' of performance measures, covering inputs and outputs, both tangible and intangible. The metrics board includes cost, time, capacity, capability (effectiveness, reliability, availability, and flexibility), productivity, utilization and outcome. When identifying new performance metrics, all the related dimensions in the metrics board can be considered.

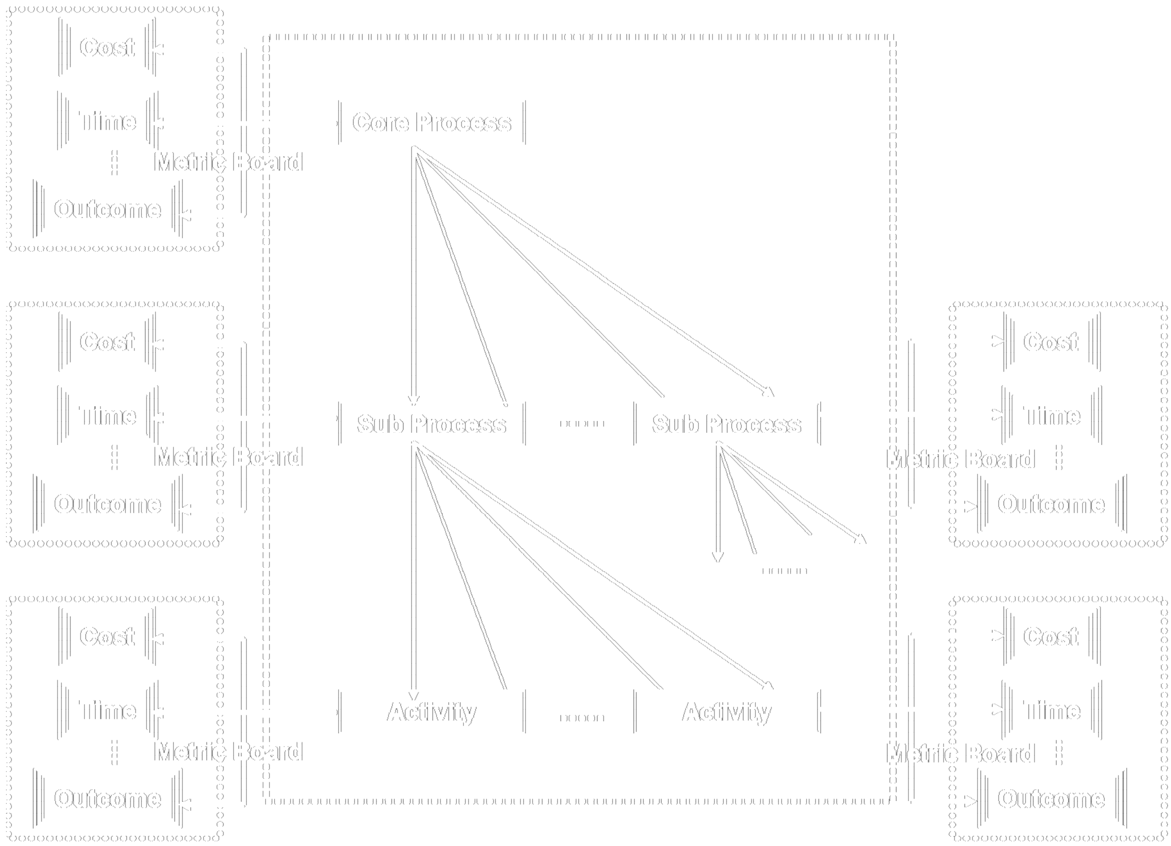

Figure 3.12: Applying Supply Chain Metrics based on Process (Chan & Qi, 2003)

Hofman (2004) described AMR Research's three-tiered Hierarchy of Supply Chain Metrics (Figure 3.13) and a top-down approach of executive assessment, diagnosis and identification of corrective action.

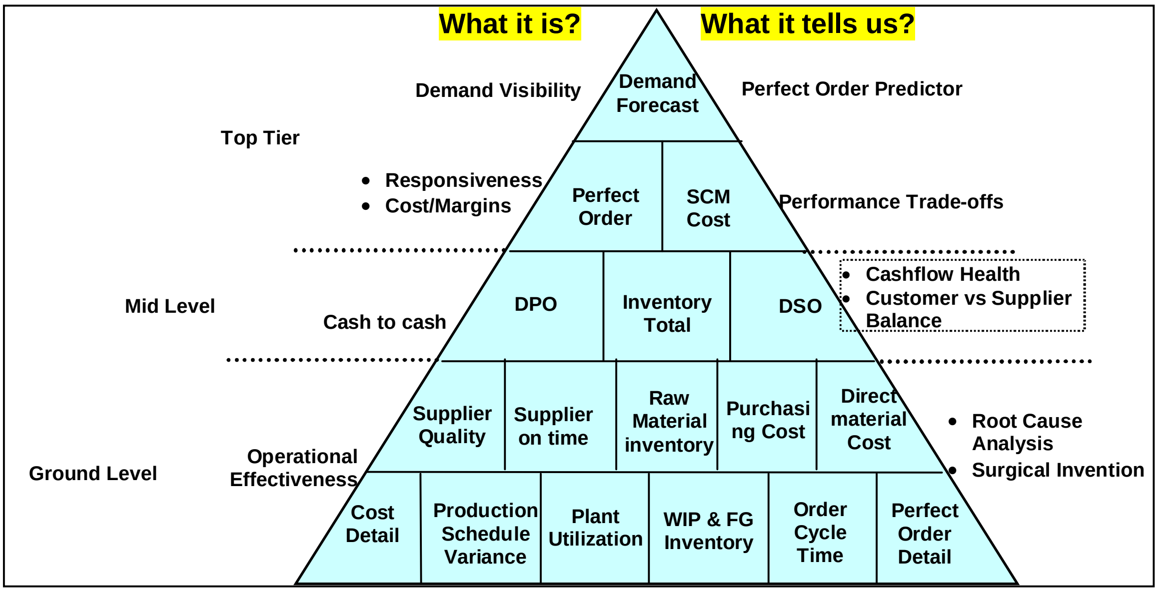

Figure 3.13: AMR Research Hierarchy of Supply Chain Metrics (Hofman, 2004)

In summary, a supply chain performance measurement framework should strive to include metrics from each different category in the following dimensions:

- The ***transformation dimension*** (Beamon, 1998): The resource measures (R), output measures (O) and flexibility measures (F).
- The ***business process dimension*** (Supply-Chain Council, 2004): top level five distinct management processes: Plan, Source, Make, Deliver and Return. This is then drilled down to important 2nd level and 3rd level processes.
- The ***business excellence dimension*** (Chan and Qi, 2003): cost, time, capacity, capability (effectiveness, reliability, availability and flexibility), productivity, utilization and outcome.
- The ***management level dimension*** (Gunasekaran et al., 2001): strategic, tactical and operational.

3.3 Inferences for New Framework Development

While the approaches described above provide guidance for supply chain measurement, they provide less help in assessing specific metrics to be used. In this regard, a key driving principle, as espoused by the Balanced Scorecard, is that measures should be aligned to strategic objectives. Supply chain strategy, however, differs for every company and depends upon its current competencies and strategic direction. Companies, for example, can generally fall into the following developmental stages that will dictate the types of measures and the degrees to which they will need to focus:

- ***Functional Excellence:*** a stage in which a company needs to develop excellence within each of its operating units such as the manufacturing, customer service, or logistics departments. Metrics for a company in this stage will need to focus on individual functional departments.

- ***Enterprise-Wide Integration:*** a stage in which a company needs to develop excellence in its cross-functional processes rather than within its individual functional departments. Metrics for a company in this stage will need to focus on cross-functional processes, materials costs and supplier delivery performance. Measured in this context only, buyers will purchase in large quantities to get volume discounts and use more suppliers for each item to ensure a low price. This behavior results in purchasing excess, potentially low quality, raw materials. It is apparent from the behavior described

- ***Extended Enterprise Integration:*** a stage in which a company needs to develop excellence in inter-enterprise processes. Metrics for a company in this stage will focus on external and cross enterprise metrics.

Historically most companies have focused their performance measurement on achieving functional excellence. With the advent of Supply Chain Management (SCM) principles aimed at integrating their supply chains, many have objectives to increase their degree of enterprise-wide integration and extended enterprise integration. In order to achieve these types of objectives, their performance measurement systems will need to align to them. Advice for these supply chain measurement systems are as described below:

Beyond Function-Based Measures

A major problem encountered with most performance measurement systems is that they are functionally focused. Within these systems, each functional area measures its performance in its own terms, with individuals evaluated based on their ability to meet objectives consistent with their department's performance measures. Individuals working under these measurement systems tend to drive operations toward improving their own area's performance, frequently at the expense of the performance of other functional areas. When each functional area sets its performance measures in isolation from those of others, it often leads to functional silos and conflicting organizational goals. These types of measures used in isolation of each other tend to create conflicting goals among functional areas as follows:

- ***Customer Service and Sales:*** In these functional areas, employees are measured by their ability to maintain customer service levels. Measured in this context only, these employees tend to drive operations toward satisfying potentially smaller sized customer orders and carrying high levels of finished goods inventories by stocking inventories in multiple locations close to customers to shorten cycle times

- ***Logistics:*** In this functional area, employees are measured by transportation and warehousing costs, and inventory levels. Measured in this context only, Logistics personnel tend to keep inventories low and batch customer orders to ensure that trucks are shipped full and picking operations are minimized. On the inbound side, these employees will want to receive full truckloads at their warehouse docks to minimize receiving costs, usually at the expense of increased inventories.

- ***Manufacturing:*** In this functional area, employees are measured in terms of manufacturing productivity. Measured in this context only, they want to make longer production runs that result in higher levels of finished goods inventories. In a make-to-order manufacturing environment there will be a tendency to consolidate customer orders into longer production runs, making them less responsive to dynamic customer demands.

- ***Purchasing:*** In this functional area, employees are typically measured by materials costs and supplier delivery performance. Measured in this context only, buyers will purchase in large quantities to get volume discounts and use more suppliers for each item to ensure a low price. This behavior results in purchasing excess, potentially low quality, raw materials.

Thus there is a need of an integrated and holistic perspective encompassing all measures, but at the same time taking entire supply chain efficiency into account. For this goal to be highest priority, it is necessary sometimes to sacrifice individual functional measure to gain overall advantage. Locally it may appear that it is the function that must be optimized, like transportation cost, but in strategic term order fulfillment in right quality at right time is also important. Thus focus on these two functional measures must be integrated to achieve excellence in both. Managers must look at things beyond functional measures and their far sightedness in this regard may help the whole chain to perform more effectively.

Include Process-Based Measures to Improve Enterprise-Wide Performance

To help integrate their supply chains, companies are starting to break down the functional silos by organizing around cross-functional processes. This is done by either creating departments responsible for an overall process or creating cross-functional teams that drive an overall process, such as: Order fulfillment (e.g., order-to-cash), New product development/introduction (e.g., concept-to-first sale or production batch) and Total cycle time (e.g., materials purchase to customer payment or cash-to-cash).

To support these organizational changes, companies are supplementing function based measures with some process-based performance measures. While this approach does not advocate the total elimination of function-based measures, it places focus on the performance of an overall process, using these measures as diagnostic information to assess what is affecting overall performance. For example, the perfect order concept measures the percent of customer orders that are flawlessly fulfilled. This metric is one that measures the effectiveness of the order fulfillment process, crossing the boundaries of functional departments. Under this measurement system, a failure during any step in the process or in any functional department, such as an item shortage on an order line or a wrong invoice, can result in a failure to meet the overall objective of flawlessly fulfilling an order. In addition to measuring the overall perfect order process, diagnostic measures for each task in the fulfillment process would need to be used. The cross-functional, process-based measures provide visibility to strategic aspects of supply chain performance, while the function-based measures are more diagnostic in nature, useful for pinpointing problem areas.

Include Cross-Enterprise Measures to Improve Extended Enterprise Performance

The cross-functional process approach to measuring supply chains is applicable for inter- as well as intra-enterprise processes. For example, many would agree that the two most important bottom-line measures of overall supply chain performance relate to:

- The availability of the right products at the point of consumption
- The total landed cost to get the products to the point of consumption (including all material, manufacturing, transportation, warehousing, and inventorying costs along the supply chain)

While these are the penultimate of supply chain measures, it is rare for one organization to control its whole supply chain's performance. Supply chains are typically comprised of many value-adding trading partners that control the portions in which they transact business. While this might be the case, SCM principles dictate that significant benefits can accrue when integrated inter-enterprise processes are in place, to synchronize and optimize the supply chain. These inter-enterprise processes should also be measured to help ensure that they are effective.

To ensure the effectiveness of cross-enterprise processes, a company should measure performance of parts of their supply chain that lie outside their own enterprise. This leads to the question of "Should you measure what is not within the domain of your enterprise or what you cannot control?" Some more specific questions relating this issue are:

- Is a manufacturer responsible for the fact that its products have poor availability on the retail shelf?
- Is a shipper responsible for the freight operations of downstream customers that pay for their own transportation or pick up products at the shipper's location?
- Is an upstream component parts supplier responsible for the fact that a manufacturer's order could not be produced due to lack of the supplier's part?
- Is a manufacturer responsible for on-time delivery to the customer after it has tendered a shipment to a transportation carrier?

Most people would answer "no" to most of these questions, stating that it is useless to measure anything on which you have little or no control. In situations, however, where performance directly or indirectly impacts the availability or cost of products at the point of consumption, the answer should be "yes" to all of these questions.

As an illustration, take the case of leading toy manufacturer's sales executive who hired people to visit a sample of some of his customer's retail stores shortly after the end of the Christmas holiday season. He had pictures taken of the shelves to assess the availability of his product following the Christmas rush. The pictures showed that in many cases the state of the shelves was a mess, with most items in disarray and most products out of stock – sure to impact the manufacturer's post-holiday sales! This executive, who took the position that his company needed to share some of the responsibility for this, started initiatives to correct it. He implemented programs that were aimed at working more closely with customers on joint store-level planning and in-store merchandizing. The strategy paid off resulting in better product availability on his customer's store shelves.

The lesson to be learned from this illustration is that at times it does makes sense to measure what you cannot control, as you may uncover a deficiency in your supply chain's performance. Once found, initiatives can be developed to address the problem and the performance measures can be used as the "call to action." These initiatives usually involve some form of program aimed at taking some level of control of upstream or downstream supply chain activities – extending beyond one's enterprise. Some manufacturers have been implementing SCM programs to extend their control. These programs and their associated performance measures include:

- ***Vendor Managed Inventory (VMI) programs:*** customer sales, in-stock availability, and inventory turns
- ***Continuous Replenishment Programs (CRP):*** customer sales, in-stock availability, and inventory turns
- ***Quick Response initiatives:*** customer sales, in-stock availability, and inventory turns
- ***Forecast-sharing programs:*** forecast accuracy, order fill rates, and inventory turns
- ***Production scheduling sharing programs:*** adherence to schedule and order cycle time
- ***Category Management programs:*** customer category sales and in-stock availability

As more companies implement SCM programs, they will be placing greater emphasis on cross-enterprise processes, extending beyond their enterprise. This will lead to the need to implement performance measurement systems that include some external measures, including some for processes that lie outside of a company's domain of control.

Based on these inferences and the research gap discussed in the previous chapter, there is a need of modification in existing models of supply chain performance. This modification is primarily required to integrate inter-firm measures, to establish cross functionality in perspectives and to identify contextual relationships between measures. The influence and dependency power of measures is what missing in present frameworks and thus this research gap must be focused to get an integrated framework in supply chain performance measurement.

3.4 Supply Chain Performance Measures: Data Extraction

Various performance measures in supply chain context are identified by these sources:

- From the detailed literature survey. The six main literature references, PMRT, 1994, Beamon, 1999, Martisons et al., 1999, Brewer & Speh, 2000, Lapide, 2000 and Gunasekaran et al., 2001 in this context are thoroughly analyzed to get supply chain measures. These measures are later on classified according to their focus towards one of the four perspectives of the balanced Scorecard.
- By the analysis of existing supply chain performance measurement frameworks
- Data extracted from three secondary empirical surveys (Supplier Performance Measurement Benchmark Survey[1] - Aberdeen Group, 2004, IBM- BCS and Industry Week Value Chain Survey[2], 2003 and McKinsey-University of Munster Study[3] on Supply Chain Champions, 2004)

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1. Between May and September 2005, Aberdeen Group examined the supplier performance measurement and improvement strategies, processes, and technologies of 197 enterprises in nearly all manufacturing and service industry segments via online survey. Responding supply management executives completed an online survey that included questions designed to determine the following: If their enterprises have supplier performance measurement programs; What types of suppliers are measured; What performance measures are tracked; Resulting performance increases since the programs were launched; Technologies used to capture, store, and share performance data; and Key program and system usage factors that affect performance improvement. Aberdeen supplemented the survey with telephone interviews with select survey respondents, other end users, and technology solution providers. Responding enterprises included the following: Job title/function: Respondents carried the following job titles: CPO, procurement/purchasing VP/director/manager, supply chain director/VP, logistics director/manager, manufacturing/operations VP/director, quality manager/engineer. Industry: Most respondents 54% came from manufacturing industries, including the automotive and high technology sectors, and various process industries. The remainder of the sample came from various service industries., Geography: The majority of respondents were from North America. Remaining respondents came from Europe and, to a lesser degree, the Asia-Pacific region. Company size: About 38% of respondents were from large enterprises (annual revenues of more than $1 billion); 35% were from mid-size enterprises (annual revenues between $50 million and $1 billion); and 27% from small businesses ($50 million or less).

2. IBM Business Consulting Services conducted the 2003 Industry Week Value Chain Survey in conjunction with Industry Week magazine. This survey identifies current practices, captures significant trends and establishes operational performance benchmarks in five key areas of supply chain management (SCM): new product development, supply chain planning, customer order management, procurement and logistics. IBM and Industry Week distributed a total of 25,000 surveys, five survey questionnaires each to 5000 Industry Week subscribers throughout the United States. Surveys included 18 to 24 questions about overall business objectives, enabling technologies and current practices, as well as core performance data, such as level of resources (full time equivalent), cycle times or efficiency rates. There were a total of 1,461 respondents, the majority from the consumer products and industrial products industries, with limited representation from distribution and transportation, high technology, energy, services, retail and wholesale industries. This major research project was performed to better understand where SCM is today and how it is evolving. This report places the research findings into an overall context and provides perspective on the continuing evolution of supply chain and value chain management principles.

3. The study of the Institute for Supply Chain Management at the University of Munster with the support from McKinsey & Co. (Thonemann & Grobpietsch, 2004) addresses two questions: Which concepts and instruments of SCM really affect supply chain performance through statistical analysis of high and low performers?; What are the key success factors for implementation (via examples and best examples from interviews)? The data sample includes 58 interviews with German companies and supporting questionnaires with quantitative questions on SC practices, qualitative aspects of SC strategy, and data on performance and structure. The 58 companies are categorized as 40 industry companies and 18 retail companies. The supply chain performance metrics used for the industry section include resource metrics: logistics cost and finished goods (FG) inventory; and service metrics: service level and delivery time. The study shows that all four measures have impact on return on sales (ROS), which is a measure of a company's profitability equal to a fiscal year's pretax income divided by total sales. For industry sections, logistics cost's impact on ROS is 1.8%, FG inventory has 1.0 to 1.5%, and service level has 0.5 to 1.0%. The leaders in the industry sections have: 4.1% logistics cost versus the industry average of 5.0%; 11 days of finished goods inventory versus an industry average of 31 days; more than 99% service level versus a 97.5% industry average; and less than 2.5 days delivery time compared with a 3.5 days industry average. These show the linkage from customer service, responsiveness, and supply chain costs to short-term financials The metrics used for the retail section include total inventory, subjective cost, shelf availability, and internal delivery time. The study shows that total inventory has 0.5 to 1.0% impact on ROS, and shelf availability has an impact of 1.0 to 3.0%. The leaders in the retail sections have 27 days of total inventory versus an average of 34 days, subjective costs of 27 versus 36, more than 97.5% shelf availability versus 96.4%, and less than 1 day internal delivery time compared with an average of 1.8 days

The possible supply chain performance measures and dimensions extracted are shown in the following tables. The detailed lists of performance measures, categorized on various criteria are compiled in Appendix-B

Table 3.3: Possible Measures identified

% automated tendering
% of demand/supply on VMI/CRP
% of resources devoted to application development
% of resources devoted to planning and review of IS activities
% of sales from new product
% of suppliers getting shared forecast
% of supply chain target costs achieved
% of applications programming with reused code
% of customer sharing forecast
% on-time deliveries
% perfect orders
% Resolution on first customer call
% scrap/rework
Accuracy of forecasting techniq.
Achievement of defect free deliveries
Adherence-to-schedule
APICS trained personnel
Application portfolio
Asset performance
Average backorder level
Average earliness of orders
Average item fill rate
Average lateness of orders
Average time required to address an end user problem
Bill-of-material accuracy
Buyer supplier partnership level
Capacity utilization
Cash flow
Cash-to-cash cycle time
Channel inventories
Container utilization
Cost of carrying inventory
Cost per operation hour
Cost per unit produced
Customer complaint
Customer disputes
Customer preferences
Customer query time
Customer response time
Customer returns
Customer sales growth & profitability
Customer satisfaction
Customer value ratio
Customer perception of flexible response
Customer satisfaction
Damaged shipments
Delivery flexibility
Delivery times
Delivery performance
Documentation accuracy

Driver reliability for performance
EDI transactions
Effectiveness of delivery invoice methods
Effectiveness of distribution planning schedule
Effectiveness of master production schedule
Efficiency of purchase order cycle time
End-of-life inventory
Establishing & maintaining relationships with user community
Expediting activities
Finished goods inventory
Finished goods inventory turns
Finished goods inventory days of supply
Flexibility of service system to meet particular customer needs
Forecast accuracy
Frequency of delivery
Income
Information carrying cost
Internet activity to suppliers/customers
In-transit inventories
Inventory accuracy
Inventory days of supply
Inventory obsolescence
Inventory shrinkage
IS specialist capability
lead time
Level of customer perceived value of product
Level of supplier's defect free deliveries Delivery lead time
Line breakdowns
Line item fill rate
Lines picked/hour
Logistics cost
Manufacturing lead time
Manufacturing productivity
Market share
Master schedule stability
Material acquisition cost
Material inventories
Material stockout
Material usage variance
Material/component quality
Mix flexibility
Net profit vs. productivity ratio
New product flexibility
New product time-to-first make
New product time-to-market
No. of backorders
No. of choices/ average response time
No. of customer contact points
No. of shared data set / total data set

No. of stock out
Number of employee suggestions
Number of end user queries handled
Obsolete inventory
On-time delivery
On-time shipment
Order entry accuracy
Order entry methods
Order fill rate
Order fulfillment
Order lead time
Order entry times
Order track and trace performance
Overtime usage
Patents awarded
Perfect order fulfillment
Performance trajectories of competing technologies
Pick accuracy
Planned process cycle time
Planning process cycle time
Plant space utilization
Premium freight charges
Product category commitment ratio
Product development cycle time
Product finalization point
Product lateness (delivery - due date)
Product quality
Production cycle time
Profit (Total revenue less expenses)
Profit margin by supply chain partner
Purchase order cycle time
Quality of delivered goods
Quality of delivery documentation
Quantity fill rate
Range of product and services
Rate of return on investment
Relative customer order response time
Repeat versus new customer sales
Research into emerging technology
Responsiveness to urgent deliveries
Retail shelf display
Return on assets
Return on capital employed
Return on investment
Return on supply chain assets
Revenue per employee
Revenues
Routing accuracy
Sales (Total revenue)
Satisfying end user needs

Schedule changes	Supplier's booking in procedures	Total supply chain cycle time
Setup/changeover costs	Supply chain cost of ownership	Transportation costs
Setups/changeovers	Supply chain cycle efficiency	Truck cube utilization
Shipment accuracy	Supply lead time against industry norm	Unit purchase cost
Shipping errors	Target fill rate achievement	Unplanned stockroom issues
Source-to-make cycle time	Time required to develop a standard size new application	Variation against budgets
Stockout probability	Time spent to repair bugs and fine-tune new application	Volume flexibility
Supplier ability to respond to quality problems	Time-to-market	Warehouse receipts
Supplier assistance in solving technical problems	Total cash flow time	Warehouse space utilization
Supplier cost saving initiatives	Total inventory	Warehousing costs
Supplier delivery performance	Total landed cost	Warranty costs
Supplier inventories	Total costs	WIP inventories
Supplier rejection rate		WIP(Work In Process)
		Yields

Based on the references of various authors these measures can be categorized into four perspectives of the Balanced Supply Chain Scorecard. The author-wise mention of these measures is shown in Table 3.3

Table 3.4: Various Measures in BSC Perspectives

1. Innovation and Learning Perspective	
PMRT (1994)	
Beamon (1999)	
Martisons et al. (1999)	IS specialist capability, Application portfolio, Research into emerging technology
Brewer and Speh (2000)	Product finalization point, Product category commitment ratio, No. of shared data sets / total data sets, Performance trajectories of competing technologies
Lapide (2000)	APICS trained personnel, Patents awarded, Time-to-market, Number of employee suggestions, Percent of sales from new product, Percent if demand/supply on VMI/CRP, Percent of customer sharing forecast, Percent of suppliers getting shared forecast, Supplier inventories, EDI transactions, Internet activity to suppliers/customers, Percent automated tendering
Gunasekaran et al. (2001)	Buyer supplier partnership level, accuracy of forecasting techniques, Product development cycle time, Supplier assistance in solving technical problems, Supplier ability to respond to quality problems, Supplier cost saving initiatives, Supplier's booking in procedures, Information carrying cost
2. Process Perspective	
PMRT (1994)	Order fulfillment, lead time, Inventory days of supply
Beamon (1999)	Stockout probability, No. of backorders, No. of stockout, Average backorder level, Inventory obsolescence, WIP(Work In Process), Finished goods inventory, Shipping errors, Manufacturing lead time, Target fill rate achievement, Average item fill rate, Product lateness (delivery date minus due date), Average lateness of orders, Average earliness of orders, Percent on-time deliveries, Volume flexibility, Delivery flexibility, Mix flexibility, New product flexibility
Martisons et al. (1999)	Percentage of resources devoted to planning and review of IS activities, Percentage of resources devoted to application development, Time required to develop a standard size new application, Percentage of applications programming with reused code, Time spent to repair bugs and fine-tune new application, Number of end user queries handled, Average time required to address an end user problem
Brewer and Speh (2000)	Supply chain cycle efficiency, No. of choices/ average response time, % of supply chain target costs achieved
Lapide (2000)	Forecast accuracy, Percent perfect orders, Schedule changes, Supplier delivery performance, Material/component quality, Material stockout, Expediting activities, Product quality, Adherence-to-schedule, Yields, Setups/changeovers, Unplanned stockroom issues, Bill-of-material accuracy, Routing accuracy, Plant space utilization, Line breakdowns, Percent scrap/rework, Overtime usage, Manufacturing productivity, Master

Lapide (2000)	schedule stability, Total supply chain inventory, Channel inventories, Material inventories, WIP inventories, Finished goods inventory turns, Finished goods inventory days of supply, On-time delivery, Lines picked/hour, Damaged shipments, Inventory accuracy, Pick accuracy, Shipment accuracy, Warehouse space utilization, End-of-life inventory, Obsolete inventory, Inventory shrinkage, Documentation accuracy, Container utilization, Truck cube utilization, In-transit inventories, Premium freight charges, Warehouse receipts, New product time-to-market, New product time-to-first make, Planning process cycle time, Retail shelf display, Source-to-make cycle time, Production cycle time, On-time shipment, Delivery times, Material usage variance, Unit purchase cost, Material acquisition cost, Cost per unit produced, Setup/changeover costs, Warranty costs, Logistics cost, Cost of carrying inventory, Transportation costs, Warehousing costs
Gunasekaran et al. (2001)	Total supply chain cycle time, Range of product and services, Order lead time, Supply lead time against industry norm, Level of supplier's defect free deliveries Delivery lead time, Delivery performance, Order entry methods, Effectiveness of delivery invoice methods, Purchase order cycle time, Planned process cycle time, Effectiveness of master production schedule, Delivery reliability, Responsiveness to urgent deliveries, Effectiveness of distribution planning schedule, Cost per operation hour, Capacity utilization, Total inventory, Supplier rejection rate, Quality of delivery documentation, Efficiency of purchase order cycle time, Frequency of delivery, Driver reliability for performance, Quality of delivered goods, Achievement of defect free deliveries
3. Customer Perspective	
PMRT (1994)	Customer satisfaction, Product quality, Perfect order fulfillment
Beamon (1999)	Customer complaint, Customer response time
Martisons et al. (1999)	Customer preferences, Establishing and maintaining relationships with user community, Satisfying end user needs
Brewer and Speh (2000)	No. of customer contact points, Relative customer order response time, Customer perception of flexible response, Customer value ratio
Lapide (2000)	Customer satisfaction, Customer returns, Customer disputes, Market share, % Resolution on first customer call, Order track and trace performance, Order entry accuracy, Order entry times, Repeat versus new customer sales, Order fill rate, Line item fill rate, Quantity fill rate
Gunasekaran et al. (2001)	Customer query time, Level of customer perceived value of product, Flexibility of service system to meet particular customer needs
4. Financial Perspective	
PMRT (1994)	Asset performance, Total supply chain costs, Cash-to-cash cycle time
Beamon (1999)	Profit (Total revenue less expenses), Total Cost, Sales (Total revenue), ROI (Return On Investment)
Martisons et al. (1999)	Profit margin by supply chain partner, Supply chain cost of ownership, Cash-to-cash cycle time, Customer sales growth & profitability, Return on supply chain assets
Brewer and Speh (2000)	Asset performance, Total supply chain costs, Cash-to-cash cycle time
Lapide (2000)	Income, Total landed cost, Cash flow, Cash-to-cycle time, Revenues, Revenue per employee, Return on capital employed, Return on investment, Return on assets
Gunasekaran et al. (2001)	Total cash flow time, Net profit vs. productivity ratio, Rate of return on investment, Variation against budgets

Based on literature review various dimensions are also identified for these four perspectives. Authors have suggested many broad categories for these measures according to their characteristic clustering.

The detailed list of all these dimensions, suggested by different authors is given in tables of Appendix-B. Working definitions of measures are also given in Table B.5 of Appendix-B. The total list of possible dimensions is presented below:

Table 3.5: Possible Dimensions identified

Administration/Financial	Information Flows	Product/Process Innovation
Asset Management	Internal	Productivity
Backorders/Stockouts	Internal Facing	Profit
Cash Flow	Inventory	Protection Plan Against Substitutes
Cash-To-Cash Cycle Time	Inventory Control	Purchasing/ Manufacturing
Cost	Logistics/ Transportation	Quality
Cross-Functional	Management Level	Resource
Customer Facing	Manufacturing	Return
Customer Order Management	Marketing	Revenue Growth
Customer Service	New Product Development	ROI
Executive Level	On-Time Delivery	Shareholder Facing
Extended Enterprise	Operational Level	Status
External	Order Fulfillment	Supply Chain Planning
Fill Rate	Order Fulfillment Lead Time	Supply Chain Response Time
Financial Metrics	Outbound	Time
Flexibility	Output	Total Supply Chain Management Costs
Flexible Response	Partnership Management	Upside Production Flexibility
Forecast Accuracy	Perfect Order Fulfillment	
General Satisfaction	Process, Cross-Functional	
Inbound	Procurement	

These various dimensions are analyzed with respective measures they are measuring and out of these possible ones, the representative ones which are covering almost all critical measures in the four perspectives of balanced scorecard are tabulated in Table 3.5:

Table 3.6: Representative Dimensions in Perspectives

Innovative & Learning Perspective	Product/Process innovation, Partnership management, Information flows, Protection Plan against substitutes
Process Perspective	Cross-Functional, Purchasing/ Manufacturing Logistics/ Transportation
Customer Perspective	General satisfaction, Order fulfillment, Flexible response, Marketing
Financial Perspective	Revenue growth, Profit, Cash flow, ROI

3.5 Measures and Dimensions in Perspectives of Integrated BSCS

Finally based on literature review and the surveys, the dimensions are identified in each perspective and then measures are grouped in each dimension to represent it to the maximum possible extent. They show how SCM fits with the balanced scorecard framework. They illustrate that the heretofore disconnected management concepts of the balanced scorecard and SCM can compliment each other nicely. As this dialogue evolves, numerous other measures should begin to emerge as companies experiment with measuring supply chain performance.

3.5.1 Innovation and Learning Perspective

Innovation and learning perspective have 16 measures which are made up of product/process innovation, partnership management, information flow, and protection plan against substitutes. SCM performance cannot be achieved in a short term; it comes from continuing cooperation among partners. It is common knowledge that trust needs to be developed over a period of time. Hence any supply chain relationship requires constant nurturing which over time leads to a certain bond between the customer and the supplier defined by mutual norms, sentiments and friendship. It is also very obvious that supply chain managers need to be skilled in not only technical and operational expertise but also in managing issues related to relationship development (Sahay, 2003). Hence the innovation and learning perspective is very important for measuring SCM performance.

Table 3.7: Innovation and Learning Perspective (Dimensions and Measures)

Dimension	Measures
Product/Process innovation	Product finalization point, Personnel with related certificates, Training on SCM, Percentage of sales from new product, New product time-to-market, R&D Investment
Partnership management	Product category commitment ratio, VMI&CRP ratio, Trust with customer, Trust with supplier, Supplier development and evaluation system
Information flows	No. of shared data sets / total data sets, EDI transactions, Percentage of customer sharing forecast, Percentage of supplier sharing forecast
Protection Plan against substitutes	Performance trajectories of competing technologies

3.5.2 Process Perspective

The traditional BSC mainly covered the internal business process, but in SCM the inter-organizational process is very important. So BSCS needs to extend the scope of measures accordingly. The measures on the process are composed of Cross-Functional, Purchasing / Manufacturing and Logistics / transportation.

Table 3.8: Process Perspective (Dimensions and Measures)

Dimension	Measures
Cross-Functional	Forecast accuracy, Supply chain cycle efficiency, Volume flexibility, Delivery flexibility, Mix flexibility, % of supply chain target cost achieved, Inventory carrying cost
Purchasing/ Manufacturing	Supplier delivery performance, Quality of purchased goods, Raw material stockout, Manufacturing productivity, Work-in-process inventory, Adherence-to-schedule
Logistics/ transportation	Finished goods inventory, On time delivery, Shipping errors, Truck cube utilization, Logistics cost

3.5.3 Customer Perspective

Table 3.8 summarizes the measures on the customer perspective. Measures are classified into four dimensions: general satisfaction, order fulfillment, flexible response, and marketing. Most measures are common among performance measures for the customers in other literature.

Table 3.9: Customer Perspective (Dimensions and Measures)

Dimension	Measures
General satisfaction	Customer satisfaction, Repeat versus new customer sales, Customer perception of quality, Customer returns, % of resolution on first customer call
Order fulfillment	Order fill rate, Order track and trace performance
Flexible response	Relative customer order response time, Customer response time
Marketing	Market share

3.5.4 Financial Perspective

Financial perspective can be summarized by revenue, profit and ROI. Most measures in these perspectives are very similar to measures in other performance measurement tools because financial measures are very common in every performance evaluation.

Table 3.10: Financial Perspective (Dimensions and Measures)

Dimension	Measures
Revenue growth	Total revenue, Customer sales growth & profitability
Profit	Total cost, Profit (Total revenue less total cost), Profit margin of supply chain partner
Cash flow	Cash flow, Cash to cash cycle
ROI	Return on Investment, Return on supply chain assets

3.6 Proposed Theoretical Framework

There is a need for an integrated Supply Chain Performance Measurement (SCPM) system that integrates all the efforts into a cohesive system that addresses the limitations of all disparate efforts in this arena. By taking inputs from various performance measurement frameworks, the research proposes an Integrated Balanced Supply Chain Scorecard Framework (Figure 3.14).

3.6.1 Levels in Integrated BSCS Framework

For developing this integrated multi-perspective framework, the perspectives are taken as the domains in which hierarchical model of contextual linkages (construct) must be established among dimensions and among measures. These constructs are proposed for individual perspective as well as for all perspectives taken combinedly. The proposed framework is designed based on three tier structure as suggested in performance measurement system literature.

For this framework three levels identified, are Perspective, Dimension and Measures. Based on Balanced Supply Chain Scorecard concept given by Brewer & Speh (2000) and Strategy Map in performance measurement field by Kaplan & Norton (2000), integration is attempted between BSC perspectives, supply chain performance dimensions and measures at each level of the proposed framework. Each Level of this proposed model is explained below:

3.6.2 The Level One Framework, $P^1(P_k)$

This level is at the top of the proposed integrated BSCS Framework, as shown in Figure 3.14. The focal units of the framework at this level are perspectives mentioned in Balanced Scorecard, i.e. Innovation & Learning, Process, Customer and Financial. These perspectives are strategic managerial concerns for aligning performance measures with strategy and vision of the organization or system. As Strategy Map, identifies a hierarchical relationship among these four perspectives (and hence taken as the foundation for other levels), this Level One Framework is also existing in supply chain context as well. Thus the Level One Framework is taken as the motivation and base behind this proposed framework. As described in the Second Generation Balanced Scorecard (strategic linkages diagram) the Innovation and learning perspective leads to improvement in internal business processes of the organization. This improvement is having its impact on customers' service and satisfaction, which ultimately gives financial perspective a strong efficiency boost.

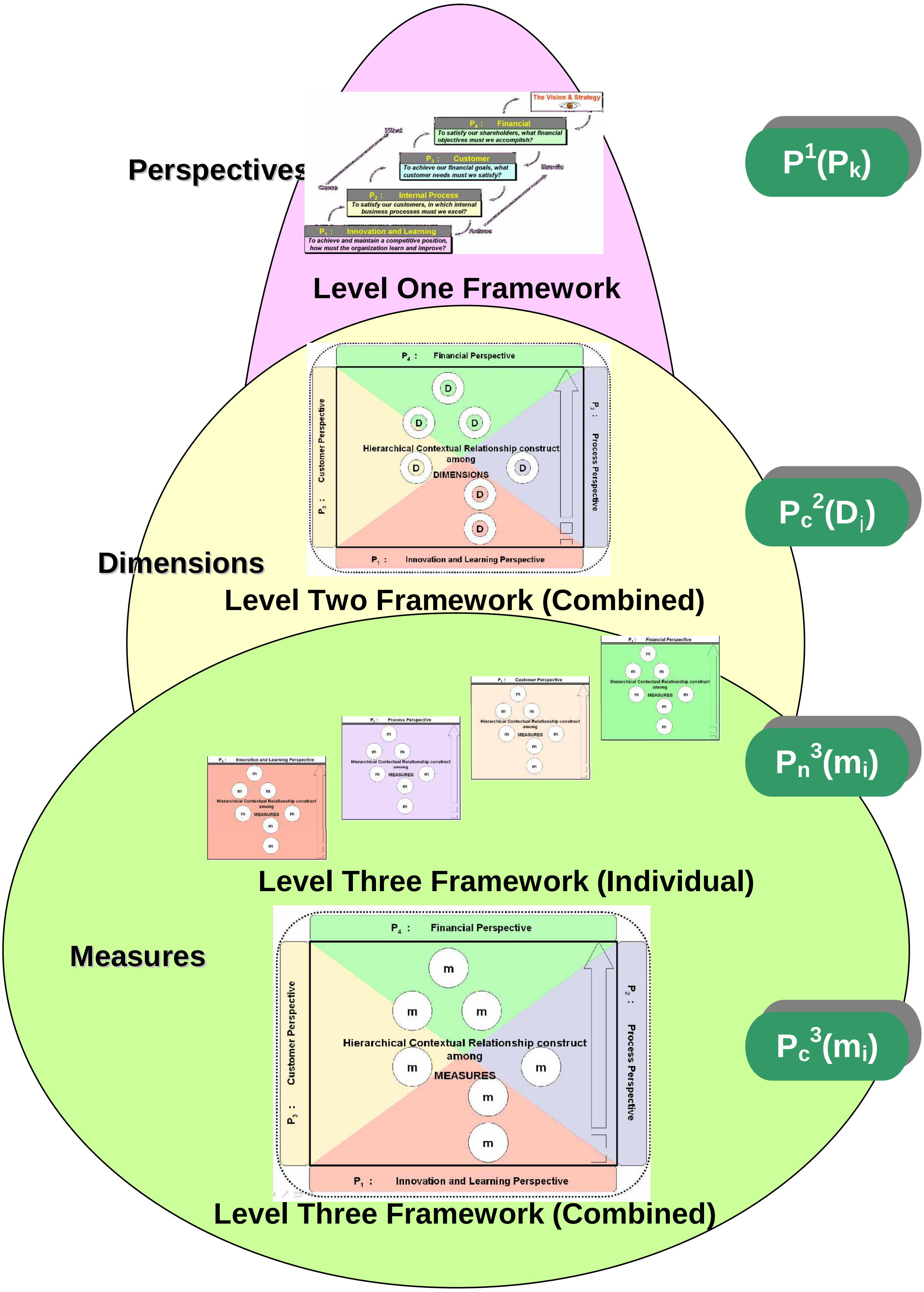

Figure 3.14: Integrated Balanced Supply Chain Scorecard (Proposed Framework)

Nomenclature used for this framework is $P^1(P_k)$, in which superscript 1 denotes the level one, and P_k denotes the Perspective. Thus this is the contextual linkage construct between ***Perspectives***. Here k varies from 1 to 4, and P_k represents four perspectives of Balanced Scorecard:

- P_1 represents Innovative and Learning perspective
- P_2 represents Process perspective
- P_3 represents Customer perspective
- P_4 represents Financial perspective

In nutshell**, The Level One Framework $P^1(P_k)$** is taken as the motivation and base behind this proposed framework. As previously mentioned it is the contextual relationship between perspectives, and already modeled in Second Generation Performance Scorecard as strategic linkage diagram. This Level One Framework construct is shown in Figure 3.15:

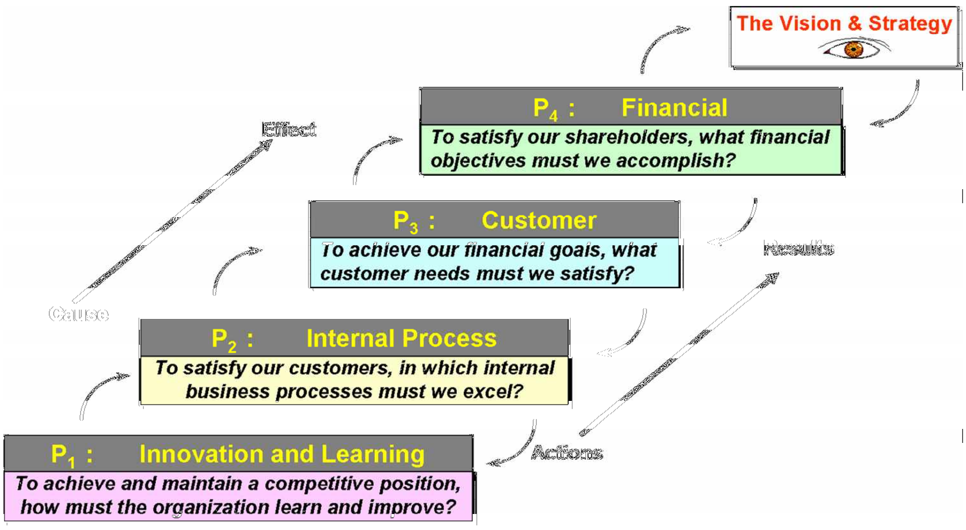

Figure 3.15: The Level One Framework, $P^1(P_k)$ (among Perspectives)

3.6.3 The Level Two Framework, [$P_k^2(D_j)$ and $P_c^2(D_j)$]

This level is at the middle of the proposed integrated BSCS Framework, as shown in Figure 3.14. The focal unit of the framework at this level is dimension. Dimensions are the broad categories of supply chain performance measures identified in each perspective of Balanced Supply Chain Scorecard. Every perspective is having three to five dimensions in it. These dimensions are broad representation of measures in the concerned performance category. From management point of view, these dimensions represent generic performance enhancement initiatives, managers should take in order to improve performance in that Perspective. This Level Two Framework can be made for dimensions in each perspective as well for the dimensions in all perspectives taken combinedly. Nomenclature used for this framework in individual perspective is $P_k^2(D_j)$, in which superscript 2 denotes the level no. i.e. two, and D_j denotes the j^{th} dimension in k^{th} Perspective. The other framework, in which dimensions of all perspectives are considered, is represented by $P_c^2(D_j)$. Here P_c denotes all perspective taken combinedly. Thus these Level Two Frameworks are the contextual linkage constructs between ***Dimensions***.

In nutshell, **The Level Two Framework (Combined) $P_c^2(D_j)$** is the contextual relationship between Dimensions of all the perspectives taken combinedly and modeling all **D_j** of all perspectives. The representative construct is shown below:

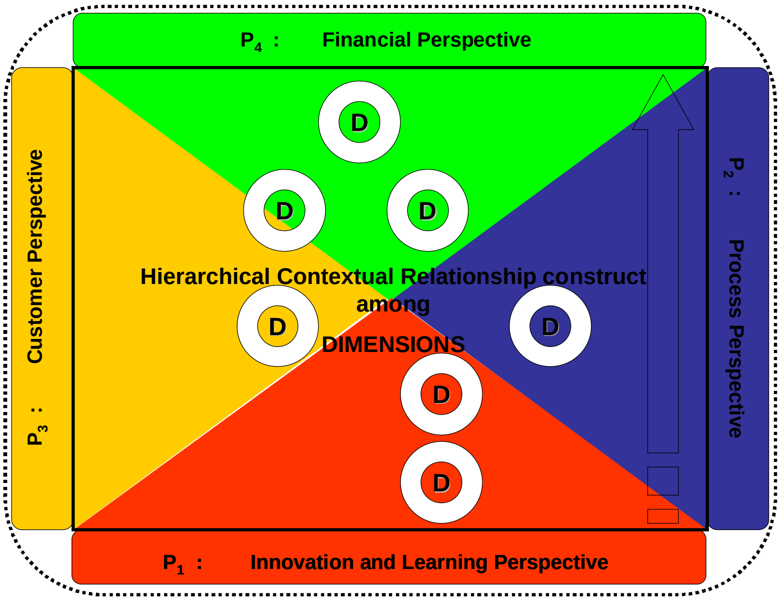

Figure 3.16: The Level Two Framework (Combined), $P_c^2(D_j)$ (among Dimensions of All Perspectives)

3.6.4 The Level Three Framework, [$P_k^3(m_i)$ and $P_c^3(m_i)$]

This level is at the bottom of the proposed integrated BSCS Framework, as shown in Figure 3.14. The focal unit of the framework at this level is *measure*. Measures are the indicator / root issues which may be qualitative as well as quantitative. These measures, as identified in supply chain performance context should be monitored efficiently, so that overall performance of the supply chain is improved. As every dimension has many measures in it and every perspective has many dimensions, it can be comprehended that each perspective has many measures in it. This Level Three Framework can be made for measures in each perspective as well for the measures in all perspectives taken combinedly. Nomenclature used for this framework in individual perspective is $P_k^3(m_i)$, in which superscript 3 denotes the level three, and m_i denotes the i^{th} measure in k^{th} Perspective. The other framework, which is considering measures of all perspectives, is represented by $P_c^3(m_i)$, in which P_c denotes all perspective taken combinedly. Thus these Level Three Frameworks are the contextual linkage constructs between ***Measures***.

The Level Three Framework (Individual) $P_k^3(m_i)$ is the contextual relationship between measures of each perspective taken individually and modeling all $\mathbf{m_i}$ in that Perspectives. The representative construct is shown below (only for one perspective here). Thus **four** such type of Level Two Framework (Individual) will be modeled to have framework for each perspective.

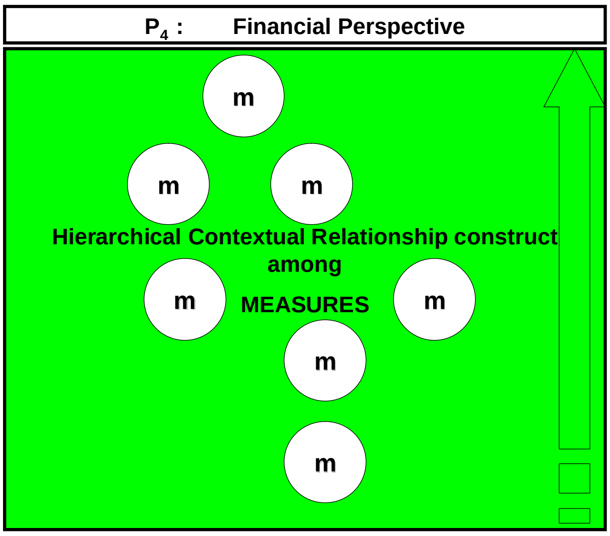

Figure 3.17: The Level Three Framework (Individual), $P_k^3(m_i)$ (among Measures in that Perspective)

The Level Three Framework (Combined) $P_c^3(m_i)$ is the contextual relationship between **measures** of all the perspectives taken combinedly and modeling all $\mathbf{m_i}$ of all perspectives. The representative construct is shown below:

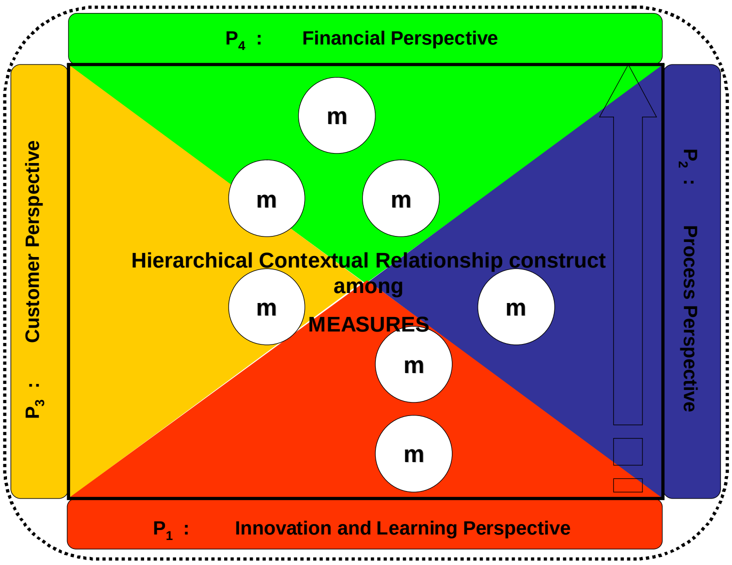

Figure 3.18: The Level Three Framework (Combined), $P_c^3(m_i)$ (among Measures of All Perspectives)

In summary, there are five constructs possible in this proposed integrated three level BSCS framework, if perspectives are considered as the classification criterion for constructs. Though it is possible to make these contextual linkage constructs among measures in each dimension also, but as Perspectives are better and more workable classification criterion, this construct is omitted from the framework.

Table 3.11: Description of Levels in Proposed Integrated BSCS Framework

Level	Description
The Level One Framework:	Contextual Relationship Diagram between Perspective ***already existing,*** $P^1(P_k)$
The Level Two Framework:	Contextual Relationship Diagram between Dimensions ***Individual perspectives,*** $P_k^2(D_j)$******* ***All perspectives (Combined),*** $P_c^2(D_j)$
The Level Three Framework:	Contextual Relationship Diagram between measures in ***Individual perspectives,*** $P_k^3(m_i)$ ***All perspectives (Combined),*** $P_c^3(m_i)$

This thesis develops The Level Two Framework (Combined), $P_c^2(D_j)$, The Level Three Framework (Individual), $P_k^3(m_i)$ and The Level Three Framework (Combined), $P_c^3(m_i)$.

*Though Level Two Framework (Individual), $P_k^2(D_j)$ for modeling dimensions in each perspective is left out from this framework, the better insight portrayed by Level Three Framework (Individual) makes its omission justifiable.

In the next chapter these frameworks are modeled using Interpretive Structural Modeling (ISM). The contextual relationship between any two measures / dimensions is identified next for this. The meta-research methodology is used for establishment of these contextual relationships.

Chapter – 4

Development of Integrated BSCS Framework

using Interpretive Structural Modeling (ISM)

The identified dimensions and the measures in previous chapter are modeled using Interpretive Structural Modeling (ISM) methodology. The contextual relationship diagram is drawn between these measures by identifying mutual influence among the measures. Key interventions, on which management should focus, are presented in decision hierarchy of the ISM model.

The ISM is employed to make model in each perspective of Balanced Scorecard (i.e. Four) and also combined model for dimensions and the measures (i.e. Two) for all the perspectives taken cumulatively.

The framework thus proposed in previous chapter is completed by making Level Two and Level Three frameworks. The driving power and dependence is also calculated in each model to plot elements classified in five categories. This MICMAC analysis is discussed in next chapter.

4.1 Rationale for choosing ISM Methodology

In this section, the rationale for choosing ISM methodology for the research is explained, and then subsequently the details of ISM methodology are enumerated. Ill-defined problems tend to be dynamic problems that involve human factors. Soft systems methodology (SSM) is generally used for dealing ill-defined problems as to what shall be done, because at the onset there is no obvious or clearly defined objective. But the main limitation of SSM is that it can be used to solve only some ill-parts of the system and not for building the system as a whole (Anonymous, 2004). In addition, SSM is a very time-intensive process. The Delphi method is a structured technique used for forecasting information in technology, business, education, science, and other fields. It follows a series of steps to develop a consensus among a group of experts. The main disadvantage associated with the Delphi method is that it is very difficult to collect questionnaires from busy individuals. The structural equation modeling (SEM) is a confirmatory approach to data analysis requiring a priori assignment of inter-variable relationships. It tests a hypothesized model statistically to determine the extent the proposed model is with the sample data (Wisner, 2003). One of the limitations of SEM is that it requires the statistical data to obtain results.

The ISM methodology on the other hand compared to the other methods described earlier has a lot of advantages. In this research, we are interested in increasing the productivity improvement of computer hardware supply chain. The productivity improvement of the computer hardware supply chain depends on a number of variables. A model depicting those key variables that should be focused on such that desired results could be achieved would be of great value to the top management. ISM can rightly be employed under such circumstances because on the basis of relationship between the variables, an overall structure can be extracted for the system under consideration. ISM is primarily intended as a group learning process, but can also used individually. The ISM process transforms unclear, poorly articulated mental models of systems into visible, well-defined models useful for many purposes (Sage, 1977).

The ISM methodology is an interactive learning process. In this a systematic application of some elementary notions of graph theory is used in such a way that theoretical, conceptual, and computational leverage are exploited to explain the complex pattern of contextual relationship among a set of variables (Malone, 1975). ISM is intended for use when desired to utilize systematic and logical thinking to approach a complex issue under consideration. It can act as a tool for imposing order and direction on the complexity of relationships among the variables (Sage, 1977, Singh et al., 2003 and Jharkharia & Shankar, 2004). An examination of the direct and indirect relationships among variables can give a clearer picture of the situation than considering individual variables alone in isolation. There are few limitations of the ISM methodology. The contextual relation among the variables always depends on the user's knowledge and familiarity with the firm, its operations, and its industry. Therefore the biasing of the person who is judging the variables might influence the final result. ISM can only act as a tool for imposing order and direction on the complexity of relationships among the variables. It does not give any weightage associated with the variables.

4.2 Interpretive Structural Modeling (ISM)

Interpretive structural modeling (ISM) is an effective methodology for dealing with complex issues. The methodology of ISM is an interactive learning process. In this, a set of different and directly related variables affecting the system under consideration is structured into a comprehensive systemic model.

It has been used for over 30 years by specially trained consultants to help their clients understand complex situations and find solutions to complex problems. First proposed by J. Warfield (1974), ISM is a computer-assisted learning process that enables individuals or groups to develop a map of the complex relationships between the many elements involved in a complex situation. ISM is often used to provide a fundamental understanding of complex situations as well as to put together a course of action for solving a problem. It allows researchers and managers to gain a deeper understanding of the relationships among key issues, and portrays the structure of a complex problem under study in graphical mode. The methodology of ISM can act as a tool for imposing order and direction on the complexity of relationships among elements of a system (Sage, 1977 and Singh et al., 2003).

Saxena et al. (1992) applied the ISM methodology for the modeling of variables of energy conservation in Indian cement industry and identified the key variables using direct as well as indirect interrelationships among the variables. Sharma et al. (1995) used the ISM methodology to develop a hierarchy of action required to achieve the future objective of waste management in India. Mandal and Deshmukh (1994) have employed the ISM to analyze some of the important vendor selection criteria and have shown the interrelationships of criteria and their levels. They have also categorized these criteria depending on their driving power and dependence. Ravi and Shankar (2005b) has used ISM framework for analyzing interactions among the barriers of reverse logistics, Ilyas et al. (2005) have employed ISM for critical determinants of an effective value-chain in a digital environment. Ravi et al. (2005a) modeled productivity improvement of a computer hardware supply chain by using ISM.

The application of ISM typically forces managers to reassess perceived priorities and improves their understanding of the linkages among key concerns. The ISM methodology is interpretive from the fact that as the judgment of the group decides whether and how the variables are related. It is structural too, as on the basis of relationship; an overall structure is extracted from the complex set of variables. It is a modeling technique in which the specific relationships of the variables and the overall structure of the system under consideration are portrayed in a digraph model.

ISM is primarily intended as a group learning process, but it can also be used individually. The various steps involved in the ISM methodology are as follows:

- Step 1: Elements affecting the system under consideration are listed, which can be Objectives, Actions, and Individuals etc.
- Step 2: From the elements identified in step 1, a contextual relationship is established among elements with respect to which pairs of elements would be examined.
- Step 3: A Structural Self-Interaction Matrix (SSIM) is developed for elements, which indicates pairwise relationships among elements of the system under consideration.
- Step 4: Reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a element A is related to B, and element B is related to element C, then element A is necessarily related to element C.
- Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels.
- Step 6: Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.
- Step 7: The resultant digraph is converted into an ISM, by replacing element nodes with statements.
- Step 8: The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

The schematic flow diagram of the different steps in ISM is given in Figure 4.1

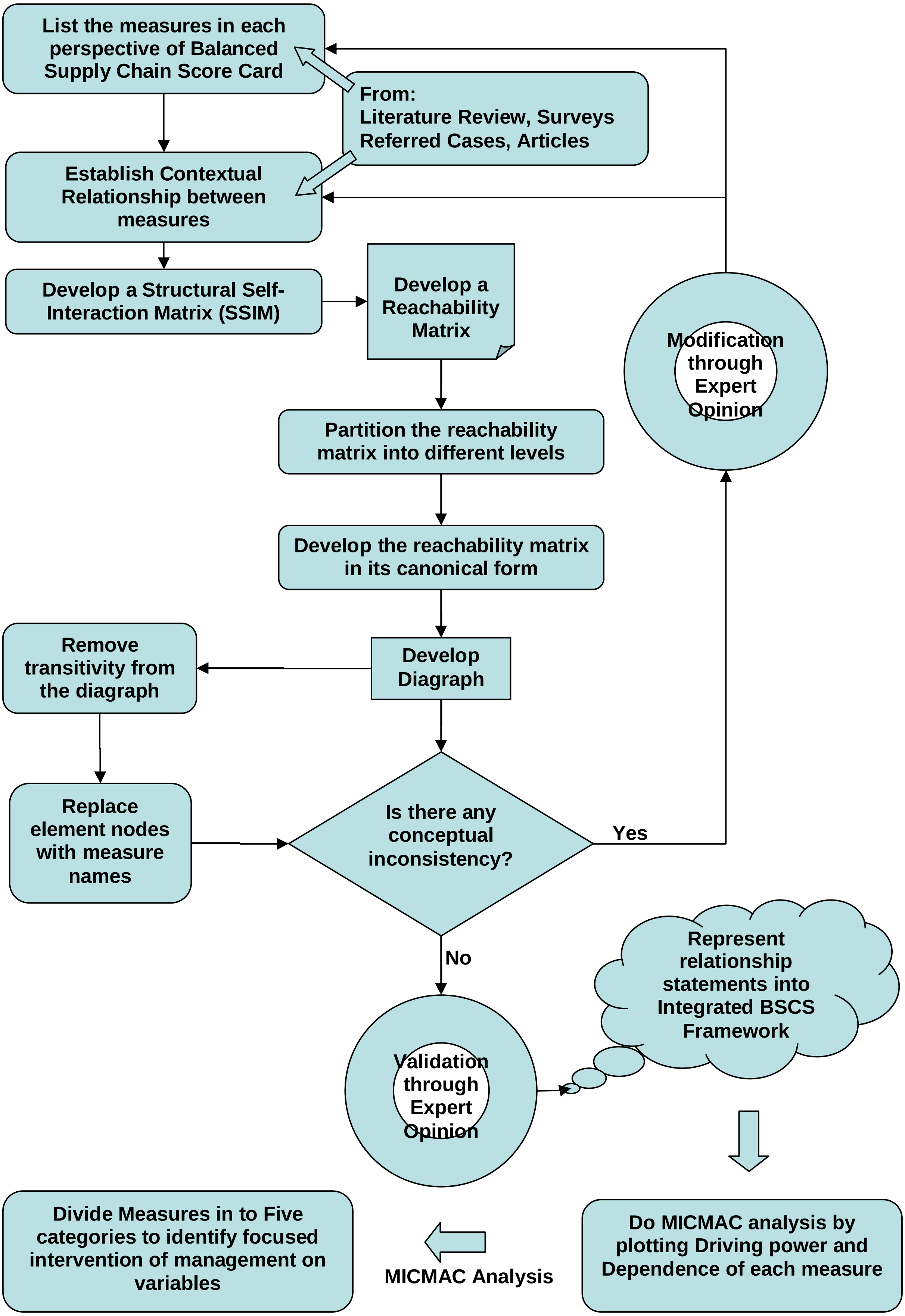

Figure 4.1: Flow Diagram for preparing ISM

4.3 Contextual Relationships between Elements

The contextual relationships between various measures (and dimensions) are established primarily on the basis of meta-research methodology (research about the research). Listed below are the sources from which the data and relationships are extracted, are:

- From the detailed literature survey
- On the basis of cases and articles listed in Appendix-C. For each of these contextual relationships in Structural Self-Interaction Matrix, the proper reference of the concerned case, article and survey is mentioned.
- Inferences extracted from three secondary empirical surveys (Supplier Performance Measurement Benchmark Survey[1] - Aberdeen Group, 2004, IBM- BCS and Industry Week Value Chain Survey[2], 2003 and McKinsey-University of Munster Study[3] on Supply Chain Champions, 2004)

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1. Between May and September 2005, Aberdeen Group examined the supplier performance measurement and improvement strategies, processes, and technologies of 197 enterprises in nearly all manufacturing and service industry segments via online survey. Responding supply management executives completed an online survey that included questions designed to determine the following: If their enterprises have supplier performance measurement programs; What types of suppliers are measured; What performance measures are tracked; Resulting performance increases since the programs were launched; Technologies used to capture, store, and share performance data; and Key program and system usage factors that affect performance improvement. Aberdeen supplemented the survey with telephone interviews with select survey respondents, other end users, and technology solution providers. Responding enterprises included the following: Job title/function: Respondents carried the following job titles: CPO, procurement/purchasing VP/director/manager, supply chain director/VP, logistics director/manager, manufacturing/operations VP/director, quality manager/engineer. Industry: Most respondents 54% came from manufacturing industries, including the automotive and high technology sectors, and various process industries. The remainder of the sample came from various service industries. Geography: The majority of respondents were from North America. Remaining respondents came from Europe and, to a lesser degree, the Asia-Pacific region. Company size: About 38% of respondents were from large enterprises (annual revenues of more than $1 billion); 35% were from mid-size enterprises (annual revenues between $50 million and $1 billion); and 27% from small businesses ($50 million or less).

2. IBM Business Consulting Services conducted the 2003 Industry Week Value Chain Survey in conjunction with Industry Week magazine. This survey identifies current practices, captures significant trends and establishes operational performance benchmarks in five key areas of supply chain management (SCM): new product development, supply chain planning, customer order management, procurement and logistics. IBM and Industry Week distributed a total of 25,000 surveys, five survey questionnaires each to 5000 Industry Week subscribers throughout the United States. Surveys included 18 to 24 questions about overall business objectives, enabling technologies and current practices, as well as core performance data, such as level of resources (full time equivalent), cycle times or efficiency rates. There were a total of 1,461 respondents, the majority from the consumer products and industrial products industries, with limited representation from distribution and transportation, high technology, energy, services, retail and wholesale industries. This major research project was performed to better understand where SCM is today and how it is evolving. This report places the research findings into an overall context and provides perspective on the continuing evolution of supply chain and value chain management principles.

3. The study of the Institute for Supply Chain Management at the University of Munster with the support from McKinsey & Co. (Thonemann & Grobpietsch 2004) addresses two questions: Which concepts and instruments of SCM really affect supply chain performance through statistical analysis of high and low performers?; What are the key success factors for implementation (via examples and best examples from interviews)? The data sample includes 58 interviews with German companies and supporting questionnaires with quantitative questions on SC practices, qualitative aspects of SC strategy, and data on performance and structure. The 58 companies are categorized as 40 industry companies and 18 retail companies. The supply chain performance metrics used for the industry section include resource metrics: logistics cost and finished goods (FG) inventory; and service metrics: service level and delivery time. The study shows that all four measures have impact on return on sales (ROS), which is a measure of a company's profitability equal to a fiscal year's pretax income divided by total sales. For industry sections, logistics cost's impact on ROS is 1.8%, FG inventory has 1.0 to 1.5%, and service level has 0.5 to 1.0%. The leaders in the industry sections have: 4.1% logistics cost versus the industry average of 5.0%; 11 days of finished goods inventory versus an industry average of 31 days; more than 99% service level versus a 97.5% industry average; and less than 2.5 days delivery time compared with a 3.5 days industry average. These show the linkage from customer service, responsiveness, and supply chain costs to short-term financials The metrics used for the retail section include total inventory, subjective cost, shelf availability, and internal delivery time. The study shows that total inventory has 0.5 to 1.0% impact on ROS, and shelf availability has an impact of 1.0 to 3.0%. The leaders in the retail sections have 27 days of total inventory versus an average of 34 days, subjective costs of 27 versus 36, more than 97.5% shelf availability versus 96.4%, and less than 1 day internal delivery time compared with an average of 1.8 days.

4.4 The Level Two Framework (Combined) $P_c^2(D_j)$

It is the contextual relationship between **Dimensions** of all the perspectives taken combined and modeling all D_j from all Perspectives. These 15 dimensions are identified in Table 4.1

Table: 4.1: List of Dimensions in all Four Perspectives

Element No.	Dimension Symbol		Dimension
1	**D_{11}**	**:**	Revenue growth
2	**D_{12}**	**:**	Profit
3	**D_{13}**	**:**	Cash flow
4	**D_{14}**	**:**	ROI
5	**D_{21}**	**:**	General satisfaction
6	**D_{22}**	**:**	Order fulfillment
7	**D_{23}**	**:**	Flexible response
8	**D_{24}**	**:**	Marketing
9	**D_{31}**	**:**	Cross-Functional
10	**D_{32}**	**:**	Purchasing/ Manufacturing
11	**D_{33}**	**:**	Logistics/ transportation
12	**D_{41}**	**:**	Product/Process innovation
13	**D_{42}**	**:**	Partnership management
14	**D_{43}**	**:**	Information flows
15	**D_{44}**	**:**	Protection Plan against substitutes

These dimensions are identified from the discussion done in the previous chapter. These dimensions are classified in various perspectives. These dimensions are representative ones for managers to focus on broad controlling mechanism in these four perspectives. Each dimension is the broad cluster of measures at level three. Thus they represent broad performance measure, to be considered in order to get the perspective of supply chain performing well.

4.4.1 Structural Self-Interaction Matrix for $P_c^2(D_j)$

As mentioned before the contextual relationship is identified between any two dimensions at this level of proposed Integrated BSCS Framework. For this purpose the meta-research (research about the research) methodology is used which derives conclusion by gathering and interpreting qualitative and quantitative data from various sources. These contextual relationships (CR) are established, based on inferences drawn from surveys, cases, literature review and recent articles in supply chain area. The corresponding sources referred for the identification of these relationships are mentioned in Table 4.2.

Table 4.2: Case, Article and Survey Reference No. for CR in SSIM for $P_c^2(D_j)$

<table>
<tr><th></th><th></th><th></th><th>Revenue growth
1</th><th>Profit
2</th><th>Cash flow
3</th><th>ROI
4</th><th>General satisfaction
5</th><th>Order fulfillment
6</th><th>Flexible response
7</th><th>Marketing
8</th><th>Cross-Functional
9</th><th>Purchasing/ Manufacturing
10</th><th>Logistics/ transportation
11</th><th>Product/Process innovation
12</th><th>Partnership management
13</th><th>Information flows
14</th><th>Protection Plan against substitutes
15</th></tr>
<tr><td>1</td><td>Revenue growth</td><td>D_{11}</td><td></td><td>A05
A13</td><td>A07
A27</td><td>A35
A32</td><td colspan="4" rowspan="4">C04, C07, C08
S01, S02, S03</td><td colspan="3" rowspan="4">C08, C09, C12,
C16, C33, C46,
S01, S02, S03</td><td colspan="4" rowspan="4">C05, C07, C24, C63
S01, S02, S03</td></tr>
<tr><td>2</td><td>Profit</td><td>D_{12}</td><td></td><td></td><td>A63
A27</td><td>A74</td></tr>
<tr><td>3</td><td>Cash flow</td><td>D_{13}</td><td></td><td></td><td></td><td>A34
A32</td></tr>
<tr><td>4</td><td>ROI</td><td>D_{14}</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>General satisfaction</td><td>D_{21}</td><td></td><td></td><td></td><td></td><td></td><td>A18
A03</td><td>A25
A04</td><td>A59</td><td colspan="3" rowspan="4">C08, C36
S01, S02, S03</td><td colspan="4" rowspan="4">C07, C13
S01, S02, S03</td></tr>
<tr><td>6</td><td>Order fulfillment</td><td>D_{22}</td><td></td><td></td><td></td><td></td><td></td><td></td><td>A76
A06</td><td>A58
A31</td></tr>
<tr><td>7</td><td>Flexible response</td><td>D_{23}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>A65
A56</td></tr>
<tr><td>8</td><td>Marketing</td><td>D_{24}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Cross-Functional</td><td>D_{31}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>A23
A30</td><td>A68
A22</td><td colspan="4" rowspan="3">C01, C49, C63
S01, S02, S03</td></tr>
<tr><td>10</td><td>Purchasing/ Manufacturing</td><td>D_{32}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>A57
A60</td></tr>
<tr><td>11</td><td>Logistics/ transportation</td><td>D_{33}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>12</td><td>Product/Process innovation</td><td>D_{41}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>A01
A11</td><td>A03
A09</td><td>A54</td></tr>
<tr><td>13</td><td>Partnership management</td><td>D_{42}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>A55
A48</td><td>A65</td></tr>
<tr><td>14</td><td>Information flows</td><td>D_{43}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>A59
A44</td></tr>
<tr><td>15</td><td>Protection Plan against substitutes</td><td>D_{44}</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

****A** stands for **Articles and News Clippings** referred, **S** stands for **Surveys** referred and **C** stands for **Cases** referred.*
See Appendix-C.1 for details of the corresponding source no. stated here.

For analyzing the dimensions in the BSCS perspectives, a contextual relationship of “leads to” type is chosen. This means that one element leads to another element. Based on this, contextual relationship between the elements is developed. Keeping in mind the contextual relationship for each dimension, the existence of a relation between any two dimensions (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the dimension (i and j):

V: Dimension i will help alleviate Dimension j;

A: Dimension i will be alleviated by Dimension j;

X: Dimensions i and j will help achieve each other; and

O: Dimensions i and j are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 4.3).

- *General Satisfaction* (Dimension 5) helps alleviate *Marketing* (Dimension 8). This means that as efforts are made to satisfy customers in general, the market share improves. Thus, the relationship between Dimensions 5 and 8 is denoted by “V” in the SSIM.

Table: 4.3: SSIM for Dimensions in All Perspectives

			Revenue growth	Profit	Cash flow	ROI	General satisfaction	Order fulfillment	Flexible response	Marketing	Cross-Functional	Purchasing/ Manufacturing	Logistics/ transportation	Product/Process innovation	Partnership management	Information flows	Protection Plan against substitutes
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Revenue growth	D_{11}		V	A	A	A	A	A	A	O	A	A	O	A	O	A
2	Profit	D_{12}			A	A	A	A	A	A	O	A	A	A	A	O	A
3	Cash flow	D_{13}				A	O	A	O	A	O	O	O	O	O	O	O
4	ROI	D_{14}					O	A	A	V	O	A	A	A	O	A	A
5	General satisfaction	D_{21}						A	A	V	O	O	A	A	O	A	O
6	Order fulfillment	D_{22}							A	V	A	A	A	O	A	A	O
7	Flexible response	D_{23}								V	A	A	A	A	A	A	O
8	Marketing	D_{24}									A	A	A	A	O	O	A
9	Cross-Functional	D_{31}										A	A	O	O	A	A
10	Purchasing/ Manufacturing	D_{32}											O	A	A	A	O
11	Logistics/ transportation	D_{33}												O	A	A	O
12	Product/Process innovation	D_{41}													A	A	A
13	Partnership management	D_{42}														V	O
14	Information flows	D_{43}															V
15	Protection Plan against substitutes	D_{44}															

- *General Satisfaction* (Dimension 5) can be alleviated by *Order Fulfillment* (Dimension 6), i.e. general satisfaction of customers is affected by the performance in fulfilling orders. Thus, the relationship between these dimensions is denoted by "A" in the SSIM.

- No relationship exists between *Protection Plan against substitutes* (Dimension 15) and *Partnership management* (Dimension 13) and hence the relationship between these dimensions is denoted by "O" in the SSIM.

Based on similar contextual relationships, the SSIM is developed in Table 4.3 for all the 15 dimensions identified for the perspectives of BSCS.

4.4.2 Initial Reachability Matrix for $P_c^2(D_j)$

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

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

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

- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.

- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, initial reachability matrix for the measures is shown in Table 4.4. The matrix is composed of 1s and 0s. If read row-wise it tells whether there exists any direct relationship called "leads to", between the elements of any row and any column. The entry 1 in the cell represents the existence of this direct contextual relationship, while 0 denotes non-existence of any direct relationship between two elements. For example General Satisfaction (Dimension 5) leads to Profit (Dimension 2) and hence having 1 in the corresponding cell of initial reachability matrix. On the other hand General Satisfaction (Dimension 5) has no direct contextual relationship with Cash Flow (Dimension 3) and hence having 0 in the corresponding cell of initial reachability matrix.

Table 4.4: Initial Reachability Matrix for Dimensions in $P_c^2(D_j)$

			Revenue growth	Profit	Cash flow	ROI	General satisfaction	Order fulfillment	Flexible response	Marketing	Cross-Functional	Purchasing/ Manufacturing	Logistics/ transportation	Product/Process innovation	Partnership management	Information flows	Protection Plan against substitutes
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Revenue growth	D_{11}	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Profit	D_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Cash flow	D_{13}	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
4	ROI	D_{14}	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0
5	General satisfaction	D_{21}	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0
6	Order fulfillment	D_{22}	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
7	Flexible response	D_{23}	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0
8	Marketing	D_{24}	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0
9	Cross-Functional	D_{31}	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
10	Purchasing/ Manufacturing	D_{32}	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0
11	Logistics/ transportation	D_{33}	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0
12	Product/Proces s innovation	D_{41}	0	1	0	1	1	0	1	1	0	1	0	1	0	0	0
13	Partnership management	D_{42}	1	1	0	0	0	1	1	0	0	1	1	1	1	1	0
14	Information flows	D_{43}	0	0	0	1	1	1	1	0	1	1	1	1	0	1	1
15	Protection Plan against substitutes	D_{44}	1	1	0	1	0	0	0	1	1	0	0	1	0	0	1

4.4.3 Final Reachability Matrix for $P_c^2(D_j)$

The final reachability matrix is obtained by incorporating the transitivities as enumerated in Step 4 of the ISM methodology. These transitive links are shown as 1*. Thus this final reachability matrix has 1s and 1*s denoting (direct as well as indirect) existing relationships. 0s are denoting absence of any relationships (whether direct or indirect) between elements. In this Table 4.5, the driving power and dependence of each dimension are also shown. The driving power of a particular dimension is the total number of dimensions (including itself) which it may help achieve. The dependence is the total number of dimensions which may help achieving it. These driving power and dependencies will be used in the MICMAC analysis, where the dimensions will be classified into five groups of autonomous, dependent, linkage, and independent (driver) and regulating variables.

Table 4.5: Final Reachability Matrix for Dimensions in $P_c^2(D_j)$

			Revenue growth	Profit	Cash flow	ROI	General satisfaction	Order fulfillment	Flexible response	Marketing	Cross-Functional	Purchasing/ Manufacturing	Logistics/ transportation	Product/Process innovation	Partnership management	Information flows	Protection Plan against substitutes	**DRIVING POWER**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
1	Revenue growth	D_{11}	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	***2***
2	Profit	D_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	***1***
3	Cash flow	D_{13}	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	***3***
4	ROI	D_{14}	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	***5***
5	General satisfaction	D_{21}	1	1	1*	0	1	0	0	1	0	0	0	0	0	0	0	***5***
6	Order fulfillment	D_{22}	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	***7***
7	Flexible response	D_{23}	1	1	1*	1	1	1	1	1	0	0	0	0	0	0	0	***8***
8	Marketing	D_{24}	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	***4***
9	Cross-Functional	D_{31}	1*	1*	1*	1*	1*	1	1	1	1	0	0	0	0	0	0	***9***
10	Purchasing/ Manufacturing	D_{32}	1	1	1*	1	1*	1	1	1	1	1	0	0	0	0	0	***10***
11	Logistics/ transportation	D_{33}	1	1	1*	1	1	1	1	1	1	0	1	0	0	0	0	***10***
12	Product/Process innovation	D_{41}	1*	1	1*	1	1	1*	1	1	1*	1	0	1	0	0	0	***11***
13	Partnership management	D_{42}	1	1	1*	1*	1*	1	1	1*	1*	1	1	1	1	1	0	***14***
14	Information flows	D_{43}	1*	1*	1*	1	1	1	1	1*	1	1	1	1	0	1	1	***14***
15	Protection Plan against substitutes	D_{44}	1	1	1*	1	1*	1*	1*	1	1	1*	0	1	0	0	1	***12***
DEPENDENCE			***14***	***15***	***13***	***10***	***10***	***9***	***8***	***12***	***7***	***5***	***3***	***4***	***1***	***2***	***2***	***118***

4.4.4 Level Partitioning of Reachability Matrix for $P_c^2(D_j)$

The reachability and antecedent set for each Dimension is found out from final reachability matrix. The reachability set for a particular element consists of the element itself and the other elements, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all elements. The element for which the reachability and the intersection sets are the same is given the top-level element in the ISM hierarchy, which would not help achieve any other element above their own level. After the identification of the top-level element, it is discarded from the other remaining.

Table 4.6: Level Partitioning for Dimensions in $P_c^2(D_j)$

Iteration 1

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 2	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1	
2	2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	2	I
3	1, 2, 3	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	3	
4	1, 2, 3, 4, 8	4, 6, 7, 9, 10, 11, 12, 13, 14, 15	4	
5	1, 2, 3, 5, 8	5, 6, 7, 9, 10, 11, 12, 13, 14, 15	5	
6	1, 2, 3, 4, 5, 6, 8	6, 7, 9, 10, 11, 12, 13, 14, 15	6	
7	1, 2, 3, 4, 5, 6, 7, 8	7, 9, 10, 11, 12, 13, 14, 15	7	
8	1, 2, 3, 8	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	8	
9	1, 2, 3, 4, 5, 6, 7, 8, 9	9, 10, 11, 12, 13, 14, 15	9	
10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	10, 12, 13, 14, 15	10	
11	1, 2, 3, 4, 5, 6, 7, 8, 9, 11	11, 13, 14	11	
12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12	12, 13, 14, 15	12	
13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	13	13	
14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	13, 14	14	
15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15	14, 15	15	

Iteration 2

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1	II
3	1, 3	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	3	
4	1, 3, 4, 8	4, 6, 7, 9, 10, 11, 12, 13, 14, 15	4	
5	1, 3, 5, 8	5, 6, 7, 9, 10, 11, 12, 13, 14, 15	5	
6	1, 3, 4, 5, 6, 8	6, 7, 9, 10, 11, 12, 13, 14, 15	6	
7	1, 3, 4, 5, 6, 7, 8	7, 9, 10, 11, 12, 13, 14, 15	7	
8	1, 3, 8	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	8	
9	1, 3, 4, 5, 6, 7, 8, 9	9, 10, 11, 12, 13, 14, 15	9	
10	1, 3, 4, 5, 6, 7, 8, 9, 10	10, 12, 13, 14, 15	10	
11	1, 3, 4, 5, 6, 7, 8, 9, 11	11, 13, 14	11	
12	1, 3, 4, 5, 6, 7, 8, 9, 10, 12	12, 13, 14, 15	12	
13	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	13	13	
14	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	13, 14	14	
15	1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15	14, 15	15	

Iteration 3

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
3	3	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	3	III
4	3, 4, 8	4, 6, 7, 9, 10, 11, 12, 13, 14, 15	4	
5	3, 5, 8	5, 6, 7, 9, 10, 11, 12, 13, 14, 15	5	
6	3, 4, 5, 6, 8	6, 7, 9, 10, 11, 12, 13, 14, 15	6	
7	3, 4, 5, 6, 7, 8	7, 9, 10, 11, 12, 13, 14, 15	7	
8	3, 8	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	8	
9	3, 4, 5, 6, 7, 8, 9	9, 10, 11, 12, 13, 14, 15	9	
10	3, 4, 5, 6, 7, 8, 9, 10	10, 12, 13, 14, 15	10	
11	3, 4, 5, 6, 7, 8, 9, 11	11, 13, 14	11	
12	3, 4, 5, 6, 7, 8, 9, 10, 12	12, 13, 14, 15	12	
13	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	13	13	
14	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	13, 14	14	
15	3, 4, 5, 6, 7, 8, 9, 10, 12, 15	14, 15	15	

Iteration 4

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
4	4, 8	4, 6, 7, 9, 10, 11, 12, 13, 14, 15	4	
5	5, 8	5, 6, 7, 9, 10, 11, 12, 13, 14, 15	5	
6	4, 5, 6, 8	6, 7, 9, 10, 11, 12, 13, 14, 15	6	
7	4, 5, 6, 7, 8	7, 9, 10, 11, 12, 13, 14, 15	7	
8	8	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	8	IV
9	4, 5, 6, 7, 8, 9	9, 10, 11, 12, 13, 14, 15	9	
10	4, 5, 6, 7, 8, 9, 10	10, 12, 13, 14, 15	10	
11	4, 5, 6, 7, 8, 9, 11	11, 13, 14	11	
12	4, 5, 6, 7, 8, 9, 10, 12	12, 13, 14, 15	12	
13	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	13	13	
14	4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	13, 14	14	
15	4, 5, 6, 7, 8, 9, 10, 12, 15	14, 15	15	

Iteration 5

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
4	4	4, 6, 7, 9, 10, 11, 12, 13, 14, 15	4	V
5	5	5, 6, 7, 9, 10, 11, 12, 13, 14, 15	5	V
6	4, 5, 6	6, 7, 9, 10, 11, 12, 13, 14, 15	6	
7	4, 5, 6, 7	7, 9, 10, 11, 12, 13, 14, 15	7	
9	4, 5, 6, 7, 9	9, 10, 11, 12, 13, 14, 15	9	
10	4, 5, 6, 7, 9, 10	10, 12, 13, 14, 15	10	
11	4, 5, 6, 7, 9, 11	11, 13, 14	11	
12	4, 5, 6, 7, 9, 10, 12	12, 13, 14, 15	12	
13	4, 5, 6, 7, 9, 10, 11, 12, 13, 14	13	13	
14	4, 5, 6, 7, 9, 10, 11, 12, 14, 15	13, 14	14	
15	4, 5, 6, 7, 9, 10, 12, 15	14, 15	15	

Iteration 6

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
6	6	6, 7, 9, 10, 11, 12, 13, 14, 15	6	VI
7	6, 7	7, 9, 10, 11, 12, 13, 14, 15	7	
9	6, 7, 9	9, 10, 11, 12, 13, 14, 15	9	
10	6, 7, 9, 10	10, 12, 13, 14, 15	10	
11	6, 7, 9, 11	11, 13, 14	11	
12	6, 7, 9, 10, 12	12, 13, 14, 15	12	
13	6, 7, 9, 10, 11, 12, 13, 14	13	13	
14	6, 7, 9, 10, 11, 12, 14, 15	13, 14	14	
15	6, 7, 9, 10, 12, 15	14, 15	15	

Iteration 7

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
7	7	7, 9, 10, 11, 12, 13, 14, 15	7	VII
9	7, 9	9, 10, 11, 12, 13, 14, 15	9	
10	7, 9, 10	10, 12, 13, 14, 15	10	
11	7, 9, 11	11, 13, 14	11	
12	7, 9, 10, 12	12, 13, 14, 15	12	
13	7, 9, 10, 11, 12, 13, 14	13	13	
14	7, 9, 10, 11, 12, 14, 15	13, 14	14	
15	7, 9, 10, 12, 15	14, 15	15	

Iteration 8

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
9	9	9, 10, 11, 12, 13, 14, 15	9	VIII
10	9, 10	10, 12, 13, 14, 15	10	
11	9, 11	11, 13, 14	11	
12	9, 10, 12	12, 13, 14, 15	12	
13	9, 10, 11, 12, 13, 14	13	13	
14	9, 10, 11, 12, 14, 15	13, 14	14	
15	9, 10, 12, 15	14, 15	15	

Iteration 9

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
10	10	10, 12, 13, 14, 15	10	IX
11	11	11, 13, 14	11	IX
12	12	12, 13, 14, 15	12	IX
13	10, 11, 12, 13, 14	13	13	
14	10, 11, 12, 14, 15	13, 14	14	
15	10, 12, 15	14, 15	15	

Iteration 10

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
13	13, 14	13	13	
14	14, 15	13, 14	14	
15	15	14, 15	15	X

Iteration 11

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
13	13, 14	13	13	
14	14	14	14	XI

Iteration 12

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
13	13	13	13	XII

Consequently, twelve levels are identified for the dimensions. The relative position of each dimension is shown in Table 4.7 by putting it in front of the respective level.

Table 4.7: Level of Dimensions in $P_c^2(D_j)$

LEVEL	ELEMENTS
I	2
II	1
III	3
IV	8
V	4, 5
VI	6
VII	7
VIII	9
IX	10, 11, 12
X	15
XI	14
XII	13

4.4.5 Canonical form of Reachability Matrix for $P_c^2(D_j)$

The Canonical Matrix is developed by clubbing together element in the same level across rows and columns. The resultant matrix shown in below is in canonical form, i.e. with most zero (0) elements in the upper diagonal half of the Matrix and most unitary (1) elements in the lower half.

Table 4.7: Canonical Form of reachability matrix for Dimensions in $P_c^2(D_j)$

			Profit	Revenue growth	Cash flow	Marketing	ROI	General satisfaction	Order fulfillment	Flexible response	Cross-Functional	Purchasing/ Manufacturing	Logistics/ transportation	Product/Process innovation	Protection Plan against substitutes	Information flows	Partnership management	**LEVEL**
			2	**1**	**3**	**8**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**15**	**14**	**13**	
2	Profit	**D_{12}**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	***I***
1	Revenue growth	**D_{11}**	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	***II***
3	Cash flow	**D_{13}**	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	***III***
8	Marketing	**D_{24}**	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	***IV***
4	ROI	**D_{14}**	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	***V***
5	General satisfaction	**D_{21}**	1	1	1*	1	0	1	0	0	0	0	0	0	0	0	0	***V***
6	Order fulfillment	**D_{22}**	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	***VI***
7	Flexible response	**D_{23}**	1	1	1*	1	1	1	1	1	0	0	0	0	0	0	0	***VII***
9	Cross-Functional	**D_{31}**	1*	1*	1*	1	1*	1*	1	1	1	0	0	0	0	0	0	***VIII***
10	Purchasing/ Manufacturing	**D_{32}**	1	1	1*	1	1	1*	1	1	1	1	0	0	0	0	0	***IX***
11	Logistics/ transportation	**D_{33}**	1	1	1*	1	1	1	1	1	1	0	1	0	0	0	0	***IX***
12	Product/Process innovation	**D_{41}**	1	1*	1*	1	1	1	1*	1	1*	1	0	1	0	0	0	***IX***
15	Protection Plan against substitutes	**D_{44}**	1	1	1*	1	1	1*	1*	1*	1	1*	0	1	1	0	0	***X***
14	Information flows	**D_{43}**	1*	1*	1*	1*	1	1	1	1	1	1	1	1	1	1	0	***XI***
13	Partnership management	**D_{42}**	1	1	1*	1*	1*	1*	1	1	1*	1	1	1	0	1	1	***XII***
LEVEL			***I***	***II***	***III***	***IV***	***V***	***V***	***VI***	***VII***	***VIII***	***IX***	***IX***	***X***	***IX***	***XI***	***XII***	

4.4.6 Formation of ISM based Model for $P_c^2(D_j)$

From the final reachability matrix, the structural model is generated. If the relationship exists between the Measures j and i, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model, as shown in Figure 4.2, by replacing element numbers with corresponding dimension name. In context to this research it is also The Level Two Framework (Combined) between dimensions of Integrated BSCS framework.

It is observed from this figure that Partnership management is a very significant dimension to be considered in a supply chain performance measurement system as it forms the base of the ISM hierarchy. Profit is the SC performance dimension, which depicts the effectiveness of SCM, has been rightly identified as the outcome of effective SCM and this dimension has appeared at the top of the hierarchy.

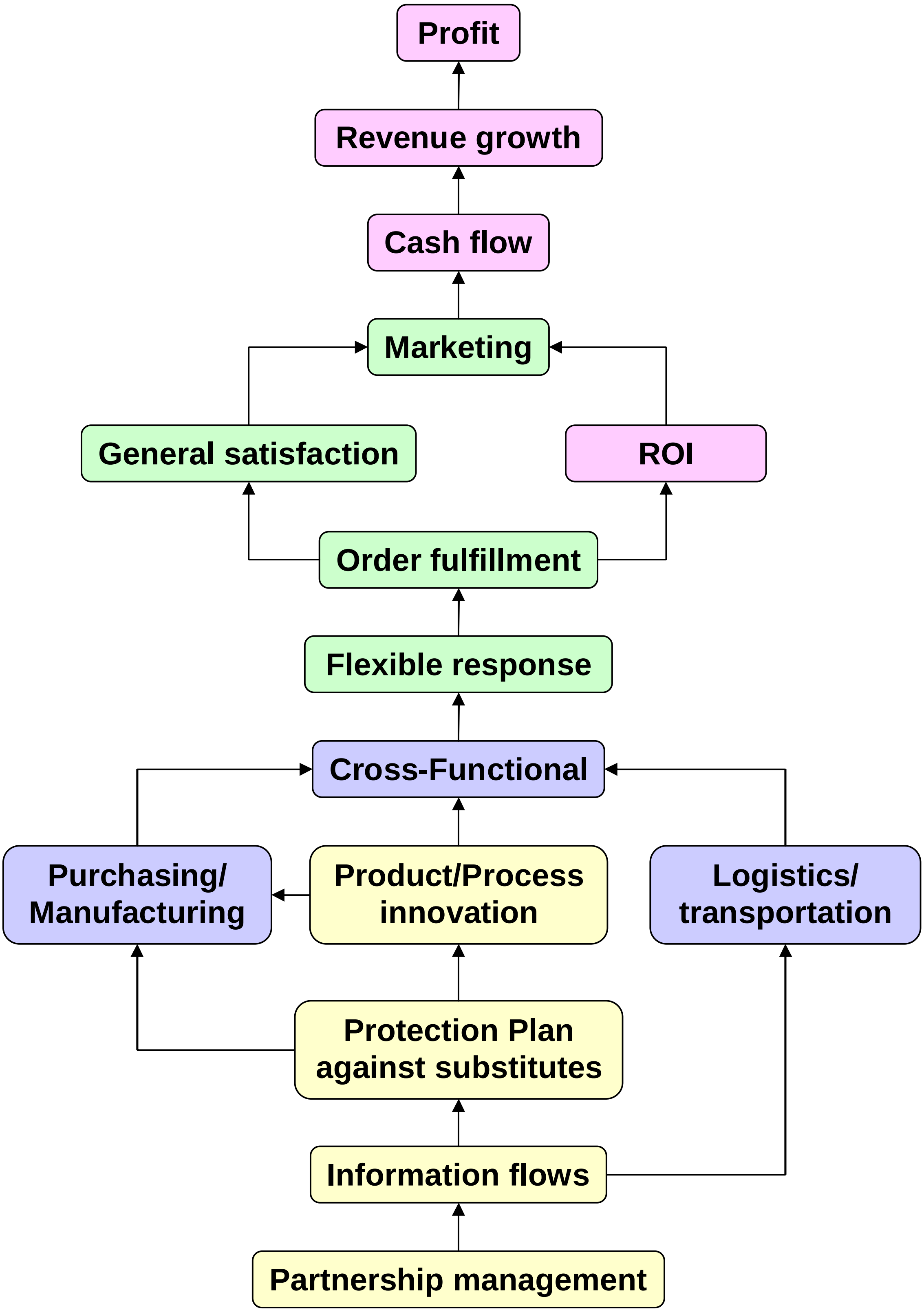


Figure 4.2: Level Two Framework (Combined) [$P_c^2(D_j)$]
(among Dimensions of All Perspectives)

4.5 The Level Three Framework for Innovation and Learning Perspective, $P_1^3(m_i)$

It is the contextual relationship between **Measures** of the innovative and learning perspective. The modeling is carried out for 16 measures identified in this perspective.

Table: 4.9: List of Measures in Innovation and Learning Perspective

Element No.	Measure Symbol		Measure
1	$^{11}m_1$	:	Product finalization point
2	$^{11}m_2$	:	Personnel with related certificates
3	$^{11}m_3$	:	Training on SCM
4	$^{11}m_4$	:	% of sales from new product
5	$^{11}m_5$	:	New product time-to-market
6	$^{12}m_1$	:	R&D Investment
7	$^{12}m_2$	:	Product category commitment ratio
8	$^{12}m_3$	:	VMI & CRP ratio
9	$^{12}m_4$	:	Trust with customer
10	$^{12}m_5$	:	Trust with supplier
11	$^{12}m_6$	:	Supplier development and evaluation system
12	$^{13}m_1$	:	% of shared data sets
13	$^{13}m_2$	:	EDI transactions
14	$^{13}m_3$	:	% of customer sharing forecast
15	$^{13}m_4$	:	% of supplier sharing forecast
16	$^{14}m_1$	:	Performance trajectories of competing technologies

Table 4.8 gives measures that focus on inter-organizational innovation and learning. The product finalization point measure addresses the increasingly important issue of post-ponement. The underlying premise of postponement is that creating finished goods that are not immediately sold commits an organization's resources, which increases the likelihood that it will experience stockouts and markdowns. The goal is to push final product completion as close to the final customer as possible in an effort to reduce inventories and minimize the risk of unsold product. The way to manage postponement is to create product or process innovations that enable a supply chain to reduce the time elapsed between finalization and customer delivery (i.e. complete product assembly late in the supply chain process). To assess the extent to which postponement is practiced, it is necessary to evaluate where in the supply chain final assembly is completed. The product category commitment ratio can be analyzed from two different perspectives. First, it measures the extent to which supply chain partnerships truly exist. Second, it assesses the potential risk to

which each partner is exposed within a supply chain relationship. The numerator captures the percentage of the seller's total product category sales that are sold to a particular customer. The denominator captures the percentage of that customer's product category needs that they bought from that seller. The ratio is calculated by dropping the percentages completely. In other words, 52% in the numerator or denominator would become 52. From a supply chain partnership viewpoint, a ratio equal to 1.0 indicates an ideal balance of power and commitment between supply chain partners. From a risk perspective, as the ratio gravitates toward its outer limits of 100 (100/1) or .01 (1/100), the imbalance of power and the level of risk grows. This type of imbalance may indicate that one partner can use its leverage to extract additional financial benefits from the relationship at the expense of another partner. This measure can be linked to others in the scorecard, such as profit margin by supply chain partner to provide convincing evidence regarding the extent to which true partnerships exist throughout the supply chain.

The number of shared data sets relative to total data sets can be used to encourage supply chain partners to create a common language for managing various processes. SCM precepts suggest that information sharing is vital to the success of supply chain partnerships. Otherwise, it would be difficult to eliminate duplication, reduce waste, cut costs, and respond flexibly to customers. Information sets such as demand forecasts, point-of-sale data, advance shipping notices, production schedules, promotion plans and schedules, strategic directions and thrust, and customer targets must be shared among supply chain partners to realize fully the potential inherent in inter-organizational integration and teamwork. Thus, the extent to which companies in a supply chain are sharing vital information sets is an important indicator of the extent to which firms are actually practicing SCM. It also indicates whether additional opportunities arc present for sharing important data sets. When each Firm uses its own terminology to identify component parts, it generates additional data that only create confusion and inefficiency and a lack of inter-organizational harmony.

The performance trajectories of competing technologies measure is designed lo help supply chains assess which emerging technologies may become a threat to their Operations. The core competency that must exist to support this measure is environmental scanning, whereby a supply chain continually monitors competitors for the emergence of substitute technologies and products that may eventually redefine how value is delivered to its customers. Once a potential substitute technology or product has been detected, the next step is to estimate its performance trajectory, or "the rate at which the performance of a product has improved and is expected to improve over time." If a potential substitute technology or product has a performance trajectory that will eventually intersect with the level of performance demanded by customers, then it is considered a threat. (Brewer & Speh, 2000)

4.5.1 Structural Self-Interaction Matrix for $P_1^3(m_i)$

As mentioned before the contextual relationships are identified between any two measures at this level of the proposed Integrated BSCS Framework. For this purpose the meta-research (research about the research) methodology is used which derives conclusion by gathering and interpreting qualitative and quantitative data from various sources. These contextual relationships (CR) are established, based on inferences drawn from surveys, cases, literature review and recent articles in supply chain area. The corresponding Article No. referred for the identification of these relationships is mentioned in Table 4.10.

Table 4.10: Article Reference No. for CR in SSIM for Innovation & Learning Perspective

		Product finalization point	Personnel with related certificates	Training on SCM	% of sales from new product	New product time-to-market	R&D Investment	Product category commitment ratio	VMI & CRP ratio	Trust with customer	Trust with supplier	Supplier development and evaluation system	% of shared data sets	EDI transactions	% of customer sharing forecast	% of supplier sharing forecast	Performance trajectories of competing technologies
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Product finalization point		**A02**	**A08**	**A08**	**A11**	**A14**	**A02**	**A02**	**A02**	**A11**	**A02**	**A17**	**A11**	**A09**	**A11**	**A47**
2	Personnel with related certificates			**A11**	**A02**	**A02**	**A14**	**A14**	**A14**	**A02**	**A17**	**A08**	**A17**	**A17**	**A08**	**A11**	**A47**
3	Training on SCM				**A11**	**A02**	**A14**	**A11**	**A14**	**A02**	**A17**	**A14**	**A43**	**A43**	**A08**	**A08**	**A47**
4	% of sales from new product					**A02**	**A14**	**A66**	**A66**	**A45**	**A40**	**A17**	**A11**	**A66**	**A33**	**A66**	**A47**
5	New product time-to-market						**A09**	**A33**	**A33**	**A52**	**A40**	**A39**	**A39**	**A33**	**A29**	**A54**	**A39**
6	R&D Investment							**A33**	**A14**	**A53**	**A40**	**A09**	**A39**	**A08**	**A54**	**A29**	**A39**
7	Product category commitment ratio								**A33**	**A66**	**A52**	**A62**	**A62**	**A54**	**A54**	**A14**	**A45**
8	VMI & CRP ratio									**A52**	**A52**	**A53**	**A62**	**A62**	**A54**	**A14**	**A45**
9	Trust with customer										**A54**	**A54**	**A78**	**A14**	**A54**	**A45**	**A45**
10	Trust with supplier											**A75**	**A75**	**A73**	**A54**	**A02**	**A45**
11	Supplier development and evaluation system												**A09**	**A78**	**A78**	**A47**	**A54**
12	% of shared data sets													**A78**	**A44**	**A47**	**A47**
13	EDI transactions														**A09**	**A09**	**A48**
14	% of customer sharing forecast															**A48**	**A48**
15	% of supplier sharing forecast																**A45**
16	Performance trajectories of competing technologies																

***A** stands for **Articles and News Clippings** referred.*
See Appendix-C.3 for details of the corresponding Article no. stated here.
*See Appendix-C.2 for **Cases** referred for this perspective.*

For analyzing the measures in the BSCS perspectives, a contextual relationship of “leads to” type is chosen. This means that one element leads to another element. Based on this, contextual relationship between the elements is developed. Keeping in mind the contextual relationship for each measure, the existence of a relation between any two measures (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the measure (i and j):

V: Measure i will help alleviate Measure j;

A: Measure i will be alleviated by Measure j;

X: Measures i and j will help achieve each other; and

O: Measures i and j are unrelated.

Table 4.11: SSIM for Measures in Innovation and Learning Perspective

		Product finalization point	Personnel with related certificates	Training on SCM	% of sales from new product	New product time-to-market	R&D Investment	Product category commitment ratio	VMI & CRP ratio	Trust with customer	Trust with supplier	Supplier development and evaluation system	% of shared data sets	EDI transactions	% of customer sharing forecast	% of supplier sharing forecast	Performance trajectories of competing technologies
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Product finalization point		A	A	A	A	A	A	A	A	A	O	A	A	A	O	A
2	Personnel with related certificates			A	O	O	V	V	O	V	V	V	V	O	V	V	V
3	Training on SCM				O	O	V	V	V	V	V	V	V	O	V	V	V
4	% of sales from new product					A	A	V	O	O	O	O	A	O	A	A	A
5	New product time-to-market						A	A	A	A	A	O	A	A	A	A	V
6	R&D Investment							V	O	O	O	O	O	O	A	A	V
7	Product category commitment ratio								A	A	A	A	A	A	A	A	V
8	VMI & CRP ratio									O	A	X	A	A	A	A	O
9	Trust with customer										O	O	V	O	V	O	O
10	Trust with supplier											X	V	O	O	V	O
11	Supplier development and evaluation system												A	A	A	V	O
12	% of shared data sets													A	V	V	V
13	EDI transactions														V	V	V
14	% of customer sharing forecast															O	V
15	% of supplier sharing forecast																O
16	Performance trajectories of competing technologies																

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 4.11).

- *Trust with supplier* (Measure 10) helps alleviate *% of supplier sharing forecast* (Measure 15). This means that as trust is built with suppliers, they tend to share forecast more. Thus, the relationship between Measures 10 and Measure 15 is denoted by "V" in the SSIM.

- *New product time to market* (Measure 5) can be alleviated by *Trust with supplier* (Measure 10), as the trust with them will reduce launching time of new product significantly due to participation and involvement of theirs. Thus, the relationship between these measures is denoted by "A" in the SSIM.

- *Trust with supplier* (Measure 10) and *Supplier development and evaluation system* (Measure 11) help achieve each other. Thus, the relationship between these measures is denoted by "X" in the SSIM.

- No relationship exists between *% of customer sharing forecast* (Measure 14) and *% of supplier sharing forecast* (Measure 15) and hence the relationship between these measures is denoted by "O" in the SSIM.

Based on similar contextual relationships, the SSIM is developed in Table 4.11 for all the 16 measures identified for this perspective of BSCS.

4.5.2 Initial Reachability Matrix for $P_1^3(m_i)$

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case.

The rules for the substitution of 1's and 0's are the following:

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

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

- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.

- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, initial reachability matrix for the measures is shown in Table 4.12.

Table 4.12: Initial Reachability Matrix for Measures in $P_1^3(m_i)$

		Product finalization point	Personnel with related certificates	Training on SCM	% of sales from new product	New product time-to-market	R&D Investment	Product category commitment ratio	VMI & CRP ratio	Trust with customer	Trust with supplier	Supplier development and evaluation system	% of shared data sets	EDI transactions	% of customer sharing forecast	% of supplier sharing forecast	Performance trajectories of competing technology
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	**Product finalization point**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	**Personnel with related certificates**	1	1	0	0	0	1	1	0	1	1	1	1	0	1	1	1
3	**Training on SCM**	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	1
4	**% of sales from new product**	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
5	**New product time-to-market**	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
6	**R&D Investment**	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1
7	**Product category commitment ratio**	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
8	**VMI & CRP ratio**	1	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0
9	**Trust with customer**	1	0	0	0	1	0	1	0	1	0	0	1	0	1	0	0
10	**Trust with supplier**	1	0	0	0	1	0	1	1	0	1	1	1	0	0	1	0
11	**Supplier development and evaluation system**	0	0	0	0	0	0	1	1	0	1	1	0	0	0	1	0
12	**% of shared data sets**	1	0	0	1	1	0	1	1	0	0	1	1	0	1	1	1
13	**EDI transactions**	1	0	0	0	1	0	1	1	0	0	1	1	1	1	1	1
14	**% of customer sharing forecast**	1	0	0	1	1	1	1	1	0	0	1	0	0	1	0	1
15	**% of supplier sharing forecast**	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0
16	**Performance trajectories of competing tech.**	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1

4.5.3 Final Reachability Matrix for $P_1^3(m_i)$

The final reachability matrix is obtained by incorporating the transitivities as enumerated in Step 4 of the ISM methodology. These transitive links are shown as 1*.

In this Table 4.13, the driving power and dependence of each measure are also shown. The driving power of a particular measure is the total number of measures (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it. These driving power and dependencies will be used in the MICMAC analysis, where the measures will be classified into five groups of autonomous, dependent, linkage, and independent (driver) and regulating variables.

Table 4.13: Final Reachability Matrix for Measures in $P_1^3(m_i)$

		Product finalization point	Personnel with related certificates	Training on SCM	% of sales from new product	New product time-to-market	R&D Investment	Product category commitment ratio	VMI & CRP ratio	Trust with customer	Trust with supplier	Supplier development and evaluation system	% of shared data sets	EDI transactions	% of customer sharing forecast	% of supplier sharing forecast	Performance trajectories of competing technology	DRIVING POWER
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	
1	**Product finalization point**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	***1***
2	**Personnel with related certificates**	1	1	0	1*	1*	1	1	1*	1	1	1	1	0	1	1	1	***14***
3	**Training on SCM**	1	1	1	1*	1*	1	1	1	1	1	1	1	0	1	1	1	***15***
4	**% of sales from new product**	1	0	0	1	1*	0	1	0	0	0	0	0	0	0	0	1*	***5***
5	**New product time-to-market**	1	0	0	1	1	0	1*	0	0	0	0	0	0	0	0	1	***5***
6	**R&D Investment**	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	***6***
7	**Product category commitment ratio**	1	0	0	1*	1	0	1	0	0	0	0	0	0	0	0	1	***5***
8	**VMI & CRP ratio**	1	0	0	1*	1	0	1	1	0	1*	1	0	0	0	1*	0	***8***
9	**Trust with customer**	1	0	0	1*	1	1*	1	1*	1	0	1*	1	0	1	0	1*	***11***
10	**Trust with supplier**	1	0	0	1*	1	1*	1	1	0	1	1	1	0	1*	1	1*	***12***
11	**Supplier development and evaluation system**	0	0	0	1*	1*	1*	1	1	0	1	1	0	0	0	1	0	***8***
12	**% of shared data sets**	1	0	0	1	1	1*	1	1	0	0	1	1	0	1	1	1	***11***
13	**EDI transactions**	1	0	0	1*	1	1*	1	1	0	0	1	1	1	1	1	1	***12***
14	**% of customer sharing forecast**	1	0	0	1	1	1	1	1	0	0	1	0	0	1	0	1	***9***
15	**% of supplier sharing forecast**	1*	0	0	1	1	1	1	1	0	0	1*	0	0	0	1	1*	***9***
16	**Performance trajectories of competing tech.**	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	***3***
	DEPENDENCE	***15***	***2***	***1***	***15***	***14***	***10***	***14***	***10***	***3***	***5***	***10***	***6***	***1***	***7***	***8***	***13***	***104***

4.5.4 Level Partitioning of Reachability Matrix for $P_1^3(m_i)$

The reachability and antecedent set for each Measure is found out from final reachability matrix. The reachability set for a particular element consists of the element itself and the other elements, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all elements. The element for which the reachability and the intersection sets are the same is given the top-level element in the ISM hierarchy, which would not help achieve any other element above their own level. After the identification of the top-level element, it is discarded from the other remaining.

Table 4.14: Level Partitioning for Measures in $P_1^3(m_i)$

Iteration 1

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16	1	I
2	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16	2, 3	2	
3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16	3	3	
4	1, 4, 5, 7, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	4, 5, 7, 16	
5	1, 4, 5, 7, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 7	
6	1, 4, 5, 6, 7, 16	2, 3, 6, 9, 10, 11, 12, 13, 14, 15	6	
7	1, 4, 5, 7, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 7	
8	1, 4, 5, 7, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
9	1, 4, 5, 6, 7, 8, 9, 11, 12, 14, 16	2, 3, 9	9	
10	1, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16	2, 3, 8, 10, 11	8, 10, 11	
11	4, 5, 6, 7, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
12	1, 4, 5, 6, 7, 8, 11, 12, 14, 15, 16	2, 3, 9, 10, 12, 13	12	
13	1, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 16	13	13	
14	1, 4, 5, 6, 7, 8, 11, 14, 16	2, 3, 9, 10, 12, 13, 14	14	
15	1, 4, 5, 6, 7, 8, 11, 15, 16	2, 3, 8, 10, 11, 12, 13, 15	8, 11, 15	
16	1, 4, 16	2, 3, 4, 6, 7, 9, 10, 12, 13, 14, 15, 16	4, 16	

Iteration 2

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16	2, 3	2	
3	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16	3	3	
4	4, 5, 7, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	4, 5, 7, 16	II
5	4, 5, 7, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,	4, 5, 7	
6	4, 5, 6, 7, 16	2, 3, 6, 9, 10, 11, 12, 13, 14, 15	6	
7	4, 5, 7, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 7	
8	4, 5, 7, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
9	4, 5, 6, 7, 8, 9, 11, 12, 14, 16	2, 3, 9	9	
10	4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16	2, 3, 8, 10, 11	8, 10, 11	
11	4, 5, 6, 7, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
12	4, 5, 6, 7, 8, 11, 12, 14, 15, 16	2, 3, 9, 10, 12, 13	12	
13	4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 16	13	13	
14	4, 5, 6, 7, 8, 11, 14, 16	2, 3, 9, 10, 12, 13, 14	14	
15	4, 5, 6, 7, 8, 11, 15, 16	2, 3, 8, 10, 11, 12, 13, 15	8, 11, 15	
16	4, 16	2, 3, 4, 6, 7, 9, 10, 12, 13, 14, 15, 16	4, 16	II

Iteration 3

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	2, 3	2	
3	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15	3	3	
5	5, 7	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	5, 7	III
6	5, 6, 7	2, 3, 6, 9, 10, 11, 12, 13, 14, 15	6	
7	5, 7	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	5, 7	III
8	5, 7, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
9	5, 6, 7, 8, 9, 11, 12, 14	2, 3, 9	9	
10	5, 6, 7, 8, 10, 11, 12, 14, 15	2, 3, 8, 10, 11	8, 10, 11	
11	5, 6, 7, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
12	5, 6, 7, 8, 11, 12, 14, 15	2, 3, 9, 10, 12, 13	12	
13	5, 6, 7, 8, 11, 12, 13, 14, 15	13	13	
14	5, 6, 7, 8, 11, 14	2, 3, 9, 10, 12, 13, 14	14	
15	5, 6, 7, 8, 11, 15	2, 3, 8, 10, 11, 12, 13, 15	8, 11, 15	

Iteration 4

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 6, 8, 9, 10, 11, 12, 14, 15	2, 3	2	
3	2, 3, 6, 8, 9, 10, 11, 12, 14, 15	3	3	
6	6	2, 3, 6, 9, 10, 11, 12, 13, 14, 15	6	IV
8	8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	IV
9	6, 8, 9, 11, 12, 14	2, 3, 9	9	
10	6, 8, 10, 11, 12, 14, 15	2, 3, 8, 10, 11	8, 10, 11	
11	6, 8, 10, 11, 15	2, 3, 8, 9, 10, 11, 12, 13, 14, 15	8, 10, 11, 15	
12	6, 8, 11, 12, 14, 15	2, 3, 9, 10, 12, 13	12	
13	6, 8, 11, 12, 13, 14, 15	13	13	
14	6, 8, 11, 14	2, 3, 9, 10, 12, 13, 14	14	
15	6, 8, 11, 15	2, 3, 8, 10, 11, 12, 13, 15	8, 11, 15	

Iteration 5

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 9, 10, 11, 12, 14, 15	2, 3	2	
3	2, 3, 9, 10, 11, 12, 14, 15	3	3	
9	9, 11, 12, 14	2, 3, 9	9	
10	10, 11, 12, 14, 15	2, 3, 10, 11	10, 11	
11	10, 11, 15	2, 3, 9, 10, 11, 12, 13, 14, 15	10, 11, 15	V
12	11, 12, 14, 15	2, 3, 9, 10, 12, 13	12	
13	11, 12, 13, 14, 15	13	13	
14	11, 14	2, 3, 9, 10, 12, 13, 14	14	
15	11, 15	2, 3, 10, 11, 12, 13, 15	11, 15	V

Iteration 6

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 9, 10, 12, 14	2, 3	2	
3	2, 3, 9, 10, 12, 14	3	3	
9	9, 12, 14	2, 3, 9	9	
10	10, 12, 14	2, 3, 10	10	
12	12, 14,	2, 3, 9, 10, 12, 13	12	
13	12, 13, 14	13	13	
14	14	2, 3, 9, 10, 12, 13, 14	14	VI

Iteration 7

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 9, 10, 12	2, 3	2	
3	2, 3, 9, 10, 12	3	3	
9	9, 12	2, 3, 9	9	
10	10, 12	2, 3, 10	10	
12	12	2, 3, 9, 10, 12, 13	12	VII
13	12, 13	13	13	

Iteration 8

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2, 9, 10	2, 3	2	
3	2, 3, 9, 10	3	3	
9	9	2, 3, 9	9	VIII
10	10	2, 3, 10	10	VIII
13	13	13	13	VIII

Iteration 9

El. E_i	Reachability Set $R(E_i)$	Antecedent Set $A(E_i)$	Intersection Set (R∩A)	Level
2	2	2, 3	2	IX
3	2, 3	3	3	

Iteration 10

El. E_i	Reachability Set $R(E_i)$	Antecedent Set $A(E_i)$	Intersection Set (R∩A)	Level
3	3	3	3	X

Consequently, ten levels are identified for the measures. The relative position of each measure is shown in Table 4.15 by putting it in front of the respective level.

Table 4.15: Level of Measures in $P_1^3(m_i)$

LEVEL	ELEMENTS
I	1
II	4, 16
III	5, 7
IV	6, 8
V	11, 15
VI	14
VII	12
VIII	9, 10, 13
IX	2
X	3

4.5.5 Canonical Form of Reachability Matrix for $P_1^3(m_i)$

The Canonical Matrix is developed by clubbing together element in the same level across rows and columns. The resultant matrix shown in below is in canonical form, i.e. with most zero (0) elements in the upper diagonal half of the Matrix and most unitary (1) elements in the lower half.

One of the observations in this canonical matrix is that few inconsistencies also exist between variables. Few higher level variables are affecting lower level variables. That means lagging variables as determined by ISM methodology are affecting leading variables. These inconsistencies are shown in the matrix by highlighting the cell in gray color. For example, VMI & CRP ratio is affecting Trust with supplier, Supplier development and evaluation system, and % of supplier sharing forecast. This is inconsistent, as the level of measure, VMI & CRP ratio is higher than the level of all other measures mentioned here. As the primary focus of ISM based model (developed later on) is to determine levels, these inconsistencies are not shown in it. These inconsistencies are arising mainly due to the limitations of meta-research methodology. Resolution of these inconsistencies is the subject of further research.

Table 4.16: Canonical Form of Reachability Matrix for Measures in $P_1^3(m_i)$

		Product finalization point	% of sales from new product	trajectories of competing	New product time-to-market	Product category commitment ratio	R&D Investment	VMI & CRP ratio	Supplier development and evaluation system	% of supplier sharing forecast	% of customer sharing forecast	% of shared data sets	Trust with customer	Trust with supplier	EDI transactions	Personnel with related certificates	Training on SCM	LEVEL
		1	**4**	**16**	**5**	**7**	**6**	**8**	**11**	**15**	**14**	**12**	**9**	**10**	**13**	**2**	**3**	
1	Product finalization point	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*I*
4	% of sales from new product	1	1	1*	1*	1	0	0	0	0	0	0	0	0	0	0	0	*II*
16	Performance trajectories of competing tech.	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	*II*
5	New product time-to-market	1	1	1	1	1*	0	0	0	0	0	0	0	0	0	0	0	*III*
7	Product category commitment ratio	1	1*	1	1	1	0	0	0	0	0	0	0	0	0	0	0	*III*
6	R&D Investment	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	*IV*
8	VMI & CRP ratio	1	1*	0	1	1	0	1	1	1*	0	0	0	1*	0	0	0	*IV*
11	Supplier development and evaluation system	0	1*	0	1*	1	1*	1	1	1	0	0	0	1	0	0	0	*V*
15	% of supplier sharing forecast	1*	1	1*	1	1	1	1	1*	1	0	0	0	0	0	0	0	*V*
14	% of customer sharing forecast	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	*VI*
12	% of shared data sets	1	1	1	1	1	1*	1	1	1	1	1	0	0	0	0	0	*VII*
9	Trust with customer	1	1*	1*	1	1	1*	1*	1*	0	1	1	1	0	0	0	0	*VIII*
10	Trust with supplier	1	1*	1*	1	1	1*	1	1	1	1*	1	0	1	0	0	0	*VIII*
13	EDI transactions	1	1*	1	1	1	1*	1	1	1	1	1	0	0	1	0	0	*VIII*
2	Personnel with related certificates	1	1*	1	1*	1	1	1*	1	1	1	1	1	1	0	1	0	*IX*
3	Training on SCM	1	1*	1	1*	1	1	1	1	1	1	1	1	1	0	1	1	*X*
LEVEL		*I*	*II*	*II*	*III*	*III*	*IV*	*IV*	*V*	*V*	*VI*	*VII*	*VIII*	*VIII*	*VIII*	*IX*	*X*	

4.5.6 Formation of ISM based Model for $P_1^3(m_i)$

From the final reachability matrix, the structural model is generated. If the relationship exists between the measures i and j, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model, as shown in Figure 4.3 by replacing element numbers with corresponding dimension name. In context to this research it is also The Level Three Framework among measures of Innovation and Learning Perspective. It is observed from this figure that Training on SCM is a very significant measure in this perspective for supply chain performance improvement as it forms the base of the ISM hierarchy. Product finalization point is the performance measure, which depicts the outcome of innovation and learning campaign. This measure has appeared at the top of the hierarchy.

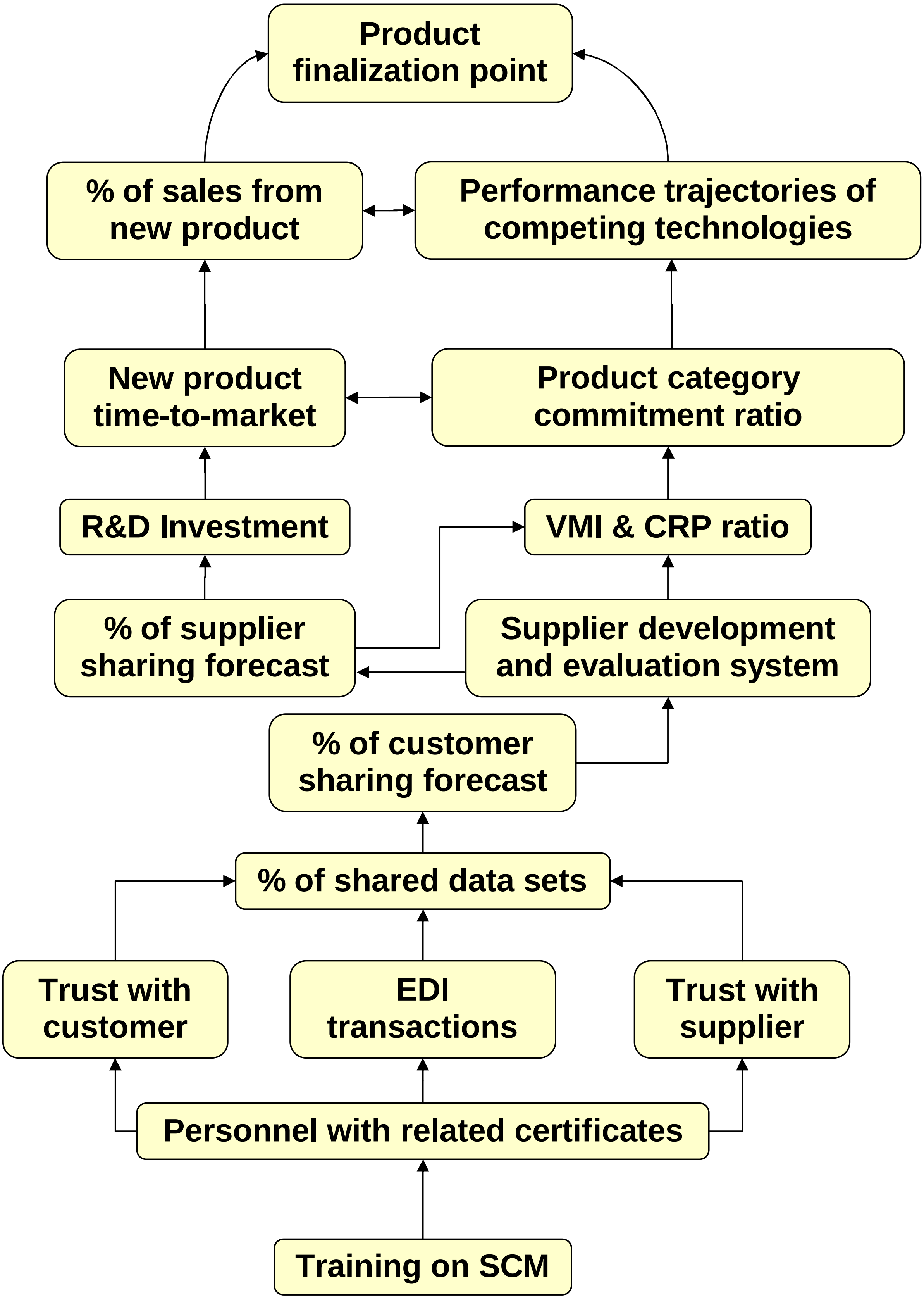


Figure 4.3: The Level Three Framework [$P_1^3(m_i)$]
(among Measures of Innovation and Learning Perspective)

4.6 The Level Three Framework for Process Perspective, $P_2^3(m_i)$

It is the contextual relationship between **Measures** of the process perspective. The modeling is carried out for 18 measures identified in this perspective.

Table: 4.17: List of Measures in Process Perspective

Element No.	Measure Symbol		Measure
1	$^{21}m_1$	:	Forecast accuracy
2	$^{21}m_2$	:	Supply chain cycle efficiency
3	$^{21}m_3$	:	Volume flexibility
4	$^{21}m_4$	:	Delivery flexibility
5	$^{21}m_5$	:	Mix flexibility
6	$^{21}m_6$	:	% of supply chain target cost achieved
7	$^{21}m_7$	:	Inventory carrying cost
8	$^{22}m_1$	:	Supplier delivery performance
9	$^{22}m_2$	:	Quality of purchased goods
10	$^{22}m_3$	:	Raw material stockout
11	$^{22}m_4$	:	Manufacturing productivity
12	$^{22}m_5$	:	Work-in-process inventory
13	$^{22}m_6$	:	Adherence-to-schedule
14	$^{23}m_1$	:	Finished goods inventory
15	$^{23}m_2$	:	On time delivery
16	$^{23}m_3$	:	Shipping errors
17	$^{23}m_4$	:	Truck cube utilization
18	$^{23}m_5$	:	Logistics cost

It is important to emphasize that these measures generally track the performance of the entire supply chain. The supply chain cost of ownership measure captures the costs across the supply chain associated with purchasing (i.e., ordering, freight, and incoming quality control), holding inventory (i.e., storage, obsolescence), poor quality (i.e., scrap, rework, warranties), and delivery failure (i.e., expediting, stock outs, premium transportation)." This provides evidence on whether the logistics processes throughout the chain are wasteful or inefficient. It is best analyzed by component of cost, such as total warehousing costs or total expediting costs, rather than by aggregating all costs into one number. Furthermore, it is necessary to evaluate this measure relative to historical performance or ideal standards.

The supply chain cycle efficiency measure is a ratio. The formula is total value-added time / total time in the supply chain. For example, if the total value-added time is ten days and the total time in the supply chain is 50 days, then the supply chain cycle efficiency equals .20.

The goal is to progress toward the ideal measure of 1.00, which indicates that non value-added time does not exist in the supply chain. Often a significant source of wasted time is the "'hand-off" between organizations. This measure helps expose those sources. Also, this type of cycle efficiency measure can be calculated within each functional department across the supply chain to pinpoint where problems lie or where functional efficiencies can be gained.

The percentage of supply chain target costs achieved can be used to ensure that process improvements in quality, lime, and flexibility are eventually translated into targeted cost reductions. This type of measure recognizes that non-financial improvements do not always automatically translate into actual spending reductions. In other words, streamlining a process may result in nothing more than the creation of additional idle capacity. Unless management takes actions to reduce spending, non-financial operating improvements will have no effect on the profits earned by the supply chain. Calculating these types of measures requires cooperation and information sharing among supply chain partners. Also, the cost-oriented measures in this section of the scorecard tend to focus on individual products and processes; this distinguishes them from measures in the financial perspective, which tend to look at performance from a broader perspective (Brewer & Speh, 2000).

4.6.1 Structural Self-Interaction Matrix for $P_2^3(m_i)$

As mentioned before the contextual relationships are identified between any two measures at this level of the proposed Integrated BSCS Framework. For this purpose the meta-research (research about the research) methodology is used which derives conclusion by gathering and interpreting qualitative and quantitative data from various sources. These contextual relationships (CR) are established, based on inferences drawn from surveys, cases, literature review and recent articles in supply chain area. The corresponding Article No. referred for the identification of these relationships is mentioned in Table 4.18.

Table 4.18: Article Reference No. for CR in SSIM for Process Perspective $P_2^3(m_i)$

		Forecast accuracy 1	Supply chain cycle efficiency 2	Volume flexibility 3	Delivery flexibility 4	Mix flexibility 5	% of supply chain target cost achieved 6	Inventory carrying cost 7	Supplier delivery performance 8	Quality of purchased goods 9	Raw material stockout 10	Manufacturing productivity 11	Work-in-process inventory 12	Adherence-to-schedule 13	Finished goods inventory 14	On time delivery 15	Shipping errors 16	Truck cube utilization 17	Logistics cost 18
1	Forecast accuracy		A70	A23	A19	A49	A19	A19	A10	A19	A61	A61	A61	A64	A12	A42	A49	A42	A12
2	Supply chain cycle efficiency			A19	A19	A38	A42	A46	A64	A81	A42	A42	A19	A64	A68	A69	A49	A42	A20
3	Volume flexibility				A23	A49	A49	A46	A22	A22	A64	A12	A64	A64	A12	A42	A81	A12	A23
4	Delivery flexibility					A23	A23	A36	A64	A64	A10	A20	A23	A49	A49	A42	A19	A12	A12
5	Mix flexibility						A80	A46	A46	A49	A10	A23	A79	A79	A61	A10	A12	A64	A12
6	% of supply chain target cost achieved							A10	A57	A60	A79	A19	A79	A16	A10	A49	A20	A12	A23
7	Inventory carrying cost								A64	A68	A69	A49	A64	A21	A49	A10	A10	A42	A12
8	Supplier delivery performance									A12	A69	A64	A10	A30	A10	A61	A49	A77	A49
9	Quality of purchased goods										A64	A68	A69	A10	A49	A49	A50	A77	A77
10	Raw material stockout											A68	A69	A50	A79	A72	A12	A61	A50
11	Manufacturing productivity												A69	A79	A46	A49	A50	A61	A50
12	Work-in-process inventory													A12	A49	A12	A72	A72	A50
13	Adherence-to-schedule														A12	A61	A72	A49	A49
14	Finished goods inventory															A50	A49	A61	A42
15	On time delivery																A50	A69	A69
16	Shipping errors																	A69	A69
17	Truck cube utilization																		A69
18	Logistics cost																		

****A** stands for **Articles and News Clippings** referred.*
See Appendix-C.3 for details of the corresponding Article no. stated here.
*See Appendix-C.2 for **Cases** referred for this perspective.*

For analyzing the measures in the BSCS perspectives, a contextual relationship of "leads to" type is chosen. This means that one element leads to another element. Based on this, contextual relationship between the elements is developed. Keeping in mind the contextual relationship for each measure, the existence of a relation between any two measures (i and j) and the associated direction of the relation is questioned.

Four symbols are used to denote the direction of relationship between the measure (i and j):

V: Measure i will help alleviate Measure j;

A: Measure i will be alleviated by Measure j;

X: Measures i and j will help achieve each other; and

O: Measures i and j are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 4.19).

Table 4.19: SSIM for Measures in Process Perspective

		Forecast accuracy	Supply chain cycle efficiency	Volume flexibility	Delivery flexibility	Mix flexibility	% of supply chain target cost achieved	Inventory carrying cost	Supplier delivery performance	Quality of purchased goods	Raw material stockout	Manufacturing productivity	Work-in-process inventory	Adherence-to-schedule	Finished goods inventory	On time delivery	Shipping errors	Truck cube utilization	Logistics cost
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	Forecast accuracy		V	V	V	V	V	V	V	O	V	V	V	V	V	V	V	V	V
2	Supply chain cycle efficiency			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
3	Volume flexibility				O	O	V	A	A	O	O	A	A	A	A	O	O	A	A
4	Delivery flexibility					O	O	O	A	O	A	A	A	A	A	A	A	A	A
5	Mix flexibility						O	A	A	A	A	A	A	A	A	O	O	O	O
6	% of supply chain target cost achieved							A	A	A	A	A	A	A	A	A	A	A	A
7	Inventory carrying cost								A	O	V	V	V	O	V	O	O	O	O
8	Supplier delivery performance									O	V	V	O	V	O	V	V	O	O
9	Quality of purchased goods										O	V	O	V	O	O	O	O	O
10	Raw material stockout											V	V	V	V	V	O	O	V
11	Manufacturing productivity												A	V	V	V	O	O	O
12	Work-in-process inventory													V	V	V	O	O	O
13	Adherence-to-schedule														V	V	A	O	V
14	Finished goods inventory															V	O	V	V
15	On time delivery																A	V	V
16	Shipping errors																	V	V
17	Truck cube utilization																		V
18	Logistics cost																		

- *Forecast accuracy* (Measure 1) helps alleviate *Supply chain cycle efficiency* (Measure 2). This means that forecast accuracy is having a lot of impact on supply chain cycle efficiency, because of many processes dependent on this accuracy of prediction. Thus, the relationship between Measure 1 and Measure 2 is denoted by "V" in the SSIM.

- *Inventory carrying cost* (Measure 7) can be alleviated by *Supplier delivery performance* (Measure 8), i.e. inventory carrying cost will be very much reduced if supplier delivers materials at the required time in right quantity. Thus, the relationship between these measures is denoted by "A" in the SSIM.

- No relationship exists between Finished goods inventory (Measure 14) and *Shipping errors* (Measure 16) and hence the relationship between these measures is denoted by "O" in the SSIM.

Based on similar contextual relationships, the SSIM is developed in Table 4.19 for all the 18 measures identified for this perspective of BSCS.

4.6.2 Initial Reachability Matrix for $P_2^3(m_i)$

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

Table 4.20: Initial Reachability Matrix for Measures in $P_2^3(m_i)$

		Forecast accuracy	Supply chain cycle efficiency	Volume flexibility	Delivery flexibility	Mix flexibility	% of supply chain target cost achieved	Inventory carrying cost	Supplier delivery performance	Quality of purchased goods	Raw material stockout	Manufacturing productivity	Work-in-process inventory	Adherence-to-schedule	Finished goods inventory	On time delivery	Shipping errors	Truck cube utilization	Logistics cost
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	**Forecast accuracy**	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
2	**Supply chain cycle efficiency**	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	**Volume flexibility**	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	**Delivery flexibility**	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	**Mix flexibility**	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6	**% of supply chain target cost achieved**	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7	**Inventory carrying cost**	0	1	1	0	1	1	1	0	0	1	1	1	0	1	0	0	0	0
8	**Supplier delivery performance**	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	0	0
9	**Quality of purchased goods**	0	1	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0
10	**Raw material stockout**	0	1	0	1	1	1	0	0	0	1	1	1	1	1	1	0	0	1
11	**Manufacturing productivity**	0	1	1	1	1	1	0	0	0	0	1	0	1	1	1	0	0	0
12	**Work-in-process inventory**	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0	0	0
13	**Adherence-to-schedule**	0	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	1
14	**Finished goods inventory**	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0	1	1
15	**On time delivery**	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	1
16	**Shipping errors**	0	1	0	1	0	1	0	0	0	0	0	0	1	0	1	1	1	1
17	**Truck cube utilization**	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1
18	**Logistics cost**	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1

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

- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.

- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, initial reachability matrix for the measures is shown in Table 4.20.

4.6.3 Final Reachability Matrix for $P_2^3(m_i)$

The final reachability matrix is obtained by incorporating the transitivities as enumerated in

Table 4.21: Final Reachability Matrix for Measures in $P_2^3(m_i)$

		Forecast accuracy	Supply chain cycle efficiency	Volume flexibility	Delivery flexibility	Mix flexibility	% of supply chain target cost achieved	Inventory carrying cost	Supplier delivery performance	Quality of purchased goods	Raw material stockout	Manufacturing productivity	Work-in-process inventory	Adherence-to-schedule	Finished goods inventory	On time delivery	Shipping errors	Truck cube utilization	Logistics cost	DRIVING POWER
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	Forecast accuracy	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	*17*
2	Supply chain cycle efficiency	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
3	Volume flexibility	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	*3*
4	Delivery flexibility	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*2*
5	Mix flexibility	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	*2*
6	% of supply chain target cost achieved	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	*2*
7	Inventory carrying cost	0	1	1	1*	1	1	1	0	0	1	1	1	1*	1	1*	0	1*	1*	*14*
8	Supplier delivery performance	0	1	1	1	1	1	1	1	0	1	1	1*	1	1*	1	1	1*	1*	*16*
9	Quality of purchased goods	0	1	1*	1*	1	1	0	0	1	0	1	0	1	1*	1*	0	0	1*	*11*
10	Raw material stockout	0	1	1*	1	1	1	0	0	0	1	1	1	1	1	1	0	1*	1	*13*
11	Manufacturing productivity	0	1	1	1	1	1	0	0	0	0	1	1*	1	1	1	0	1*	1*	*12*
12	Work-in-process inventory	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0	1*	1*	*12*
13	Adherence-to-schedule	0	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	1*	1	*10*
14	Finished goods inventory	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0	1	1	*9*
15	On time delivery	0	1	1*	1	1*	1	0	0	0	0	0	0	0	0	1	0	1	1	*8*
16	Shipping errors	0	1	1*	1	1*	1	0	0	0	0	0	0	1	1*	1	1	1	1	*11*
17	Truck cube utilization	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	*6*
18	Logistics cost	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	*5*
DEPENDENCE		*1*	*18*	*14*	*14*	*12*	*15*	*3*	*2*	*1*	*4*	*7*	*6*	*9*	*10*	*11*	*3*	*11*	*13*	*154*

Step 4 of the ISM methodology. These transitive links are shown as 1*. In this Table 4.21, the driving power and dependence of each measure are also shown. The driving power of a particular measure is the total number of measures (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it. These driving power and dependencies will be used in the MIC-MAC analysis, where the measures will be classified into five groups of autonomous, dependent, linkage, and independent (driver) and regulating variables.

4.6.4 Level Partitioning of Reachability Matrix for $P_2^3(m_i)$

The reachability and antecedent set for each Measure is found out from final reachability matrix. The reachability set for a particular element consists of the element itself and the other elements, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all elements. The element for which the reachability and the intersection sets are the same is given the top-level element in the ISM hierarchy, which would not help achieve any other element above their own level. After the identification of the top-level element, it is discarded from the other remaining.

Table 4.22: Level Partitioning for Measures in $P_2^3(m_i)$

Iteration 1

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16	1	1	
2	2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	2	I
3	2, 3, 6	1, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	3	
4	2, 4	1, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	4	
5	2, 5	1, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	5	
6	2, 6	1, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	6	
7	2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15	1, 7, 8	7	
8	2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16	1, 8	8	
9	2, 3, 4, 5, 6, 9, 11, 13, 14, 15	9	9	
10	2, 3, 4, 5, 6, 10, 11, 12, 13, 14, 15	1, 7, 8, 10	10	
11	2, 3, 4, 5, 6, 11, 12, 13, 14, 15	1, 7, 8, 9, 10, 11, 12	11, 12	
12	2, 3, 4, 5, 6, 11, 12, 13, 14, 15	1, 7, 8, 10, 11, 12	11, 12	
13	2, 3, 4, 5, 6, 13, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 16	13	
14	2, 3, 4, 5, 6, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 16	14	
15	2, 3, 4, 5, 6, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15	
16	2, 3, 4, 5, 6, 13, 14, 15, 16	1, 8, 16	16	
17	2, 3, 4, 6, 17	1, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	17	
18	2, 3, 4, 6, 18	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	18	

Iteration 2

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16	1	1	
3	3, 6	1, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	3	
4	4	1, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	4	II
5	5	1, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	5	II

6	6	1, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	6	II
7	3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15	1, 7, 8	7	
8	3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16	1, 8	8	
9	3, 4, 5, 6, 9, 11, 13, 14, 15	9	9	
10	3, 4, 5, 6, 10, 11, 12, 13, 14, 15	1, 7, 8, 10	10	
11	3, 4, 5, 6, 11, 12, 13, 14, 15	1, 7, 8, 9, 10, 11, 12	11, 12	
12	3, 4, 5, 6, 11, 12, 13, 14, 15	1, 7, 8, 10, 11, 12	11, 12	
13	3, 4, 5, 6, 13, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 16	13	
14	3, 4, 5, 6, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 16	14	
15	3, 4, 5, 6, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15	
16	3, 4, 5, 6, 13, 14, 15, 16	1, 8, 16	16	
17	3, 4, 6, 17	1, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	17	
18	3, 4, 6, 18	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	18	

Iteration 3

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 3, 7, 8, 10, 11, 12, 13, 14, 15, 16	1	1	
3	3	1, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	3	III
7	3, 7, 10, 11, 12, 13, 14, 15	1, 7, 8	7	
8	3, 7, 8, 10, 11, 12, 13, 14, 15, 16	1, 8	8	
9	3, 9, 11, 13, 14, 15	9	9	
10	3, 10, 11, 12, 13, 14, 15	1, 7, 8, 10	10	
11	3, 11, 12, 13, 14, 15	1, 7, 8, 9, 10, 11, 12	11, 12	
12	3, 11, 12, 13, 14, 15	1, 7, 8, 10, 11, 12	11, 12	
13	3, 13, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 16	13	
14	3, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 16	14	
15	3, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15	
16	3, 13, 14, 15, 16	1, 8, 16	16	
17	3, 17	1, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	17	
18	3, 18	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	18	

Iteration 4

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 7, 8, 10, 11, 12, 13, 14, 15, 16	1	1	
7	7, 10, 11, 12, 13, 14, 15	1, 7, 8	7	
8	7, 8, 10, 11, 12, 13, 14, 15, 16	1, 8	8	
9	9, 11, 13, 14, 15	9	9	
10	10, 11, 12, 13, 14, 15	1, 7, 8, 10	10	
11	11, 12, 13, 14, 15	1, 7, 8, 9, 10, 11, 12	11, 12	
12	11, 12, 13, 14, 15	1, 7, 8, 10, 11, 12	11, 12	
13	13, 14, 15	1, 7, 8, 9, 10, 11, 12, 13, 16	13	
14	14, 15	1, 7, 8, 9, 10, 11, 12, 13, 14, 16	14	
15	15	1, 7, 8, 9, 10, 11, 12, 13, 14 15, 16	15	IV
16	13, 14, 15, 16	1, 8, 16	16	
17	17	1, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	17	IV
18	18	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	18	IV

Iteration 5

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 7, 8, 10, 11, 12, 13, 14, 16	1	1	
7	7, 10, 11, 12, 13, 14	1, 7, 8	7	

8	7, 8, 10, 11, 12, 13, 14, 16	1, 8	8	
9	9, 11, 13, 14	9	9	
10	10, 11, 12, 13, 14	1, 7, 8, 10	10	
11	11, 12, 13, 14	1, 7, 8, 9, 10, 11, 12	11, 12	
12	11, 12, 13, 14	1, 7, 8, 10, 11, 12	11, 12	
13	13, 14	1, 7, 8, 9, 10, 11, 12, 13, 16	13	
14	14	1, 7, 8, 9, 10, 11, 12, 13, 14, 16	14	V
16	13, 14, 16	1, 8, 16	16	

Iteration 6

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 7, 8, 10, 11, 12, 13, 16	1	1	
7	7, 10, 11, 12, 13,	1, 7, 8	7	
8	7, 8, 10, 11, 12, 13, , 16	1, 8	8	
9	9, 11, 13	9	9	
10	10, 11, 12, 13	1, 7, 8, 10	10	
11	11, 12, 13	1, 7, 8, 9, 10, 11, 12	11, 12	
12	11, 12, 13	1, 7, 8, 10, 11, 12	11, 12	
13	13	1, 7, 8, 9, 10, 11, 12, 13, 16	13	VI
16	13, 16	1, 8, 16	16	

Iteration 7

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 7, 8, 10, 11, 12, 16	1	1	
7	7, 10, 11, 12,	1, 7, 8	7	
8	7, 8, 10, 11, 12, 16	1, 8	8	
9	9, 11	9	9	
10	10, 11, 12	1, 7, 8, 10	10	
11	11, 12	1, 7, 8, 9, 10, 11, 12	11, 12	VII
12	11, 12	1, 7, 8, 10, 11, 12	11, 12	VII
16	16	1, 8, 16	16	VII

Iteration 8

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 7, 8, 10	1	1	
7	7, 10	1, 7, 8	7	
8	7, 8, 10	1, 8	8	
9	9	9	9	VIII
10	10	1, 7, 8, 10	10	VIII

Iteration 9

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 7, 8	1	1	
7	7	1, 7, 8	7	IX
8	7, 8	1, 8	8	

Iteration 10

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 8	1	1	
8	8	1, 8	8	X

Iteration 11

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1	1	1	XI

Consequently, eleven levels are identified for the measures. The relative position of each measure is shown in Table 4.23 by putting it in front of the respective level.

Table 4.23: Level of Measures in $P_2^3(m_i)$

LEVEL	ELEMENTS
I	2
II	4, 5, 6
III	3
IV	15, 17, 18
V	14
VI	13
VII	11, 12, 16
VIII	9, 10
IX	7
X	8
XI	1

4.6.5 Canonical Form of Reachability Matrix for $P_2^3(m_i)$

The Canonical Matrix is developed by clubbing together element in the same level across rows and columns. The resultant matrix shown in below is in canonical form, i.e. with most zero (0) elements in the upper diagonal half of the Matrix and most unitary (1) elements in the lower half.

Table 4.24: Canonical Form of Reachability Matrix for Measures in $P_2^3(m_i)$

		Supply chain cycle efficiency	Delivery flexibility	Mix flexibility	% of supply chain target cost achieved	Volume flexibility	On time delivery	Truck cube utilization	Logistics cost	Finished goods inventory	Adherence-to-schedule	Manufacturing productivity	Work-in-process inventory	Shipping errors	Quality of purchased goods	Raw material stockout	Inventory carrying cost	Supplier delivery performance	Forecast accuracy	LEVEL
		2	4	5	6	3	15	17	18	14	13	11	12	16	9	10	7	8	1	
2	Supply chain cycle efficiency	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*I*
4	Delivery flexibility	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*II*
5	Mix flexibility	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*II*
6	% of supply chain target cost achieved	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*II*
3	Volume flexibility	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	*III*
15	On time delivery	1	1	1*	1	1*	1	1	1	0	0	0	0	0	0	0	0	0	0	*IV*
17	Truck cube utilization	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	*IV*
18	Logistics cost	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	*IV*
14	Finished goods inventory	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	*V*
13	Adherence-to-schedule	1	1	1	1	1	1	1*	1	1	1	0	0	0	0	0	0	0	0	*VI*
11	Manufacturing productivity	1	1	1	1	1	1	1*	1*	1	1	1	1*	0	0	0	0	0	0	*VII*
12	Work-in-process inventory	1	1	1	1	1	1	1*	1*	1	1	1	1	0	0	0	0	0	0	*VII*
16	Shipping errors	1	1	1*	1	1*	1	1	1	1*	1	0	0	1	0	0	0	0	0	*VII*
9	Quality of purchased goods	1	1*	1	1	1*	1*	0	1*	1*	1	1	0	0	1	0	0	0	0	*VIII*
10	Raw material stockout	1	1	1	1	1*	1	1*	1	1	1	1	1	0	0	1	0	0	0	*VIII*
7	Inventory carrying cost	1	1*	1	1	1	1*	1*	1*	1	1*	1	1	0	0	1	1	0	0	*IX*
8	Supplier delivery performance	1	1	1	1	1	1	1*	1*	1*	1	1	1*	1	0	1	1	1	0	*X*
1	Forecast accuracy	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	*XI*
LEVEL		*I*	*II*	*II*	*II*	*III*	*IV*	*IV*	*IV*	*V*	*VI*	*VII*	*VII*	*VII*	*VIII*	*VIII*	*IX*	*X*	*XI*	

4.6.6 Formation of ISM based Model for $P_2^3(m_i)$

From the final reachability matrix, the structural model is generated. If the relationship exists between the Measures j and i, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model, as shown in the Figure 4.4 by replacing element numbers with corresponding measure name. In context to this research it is also The Level Two Framework among measures of Process Perspective.

It is observed from this figure that Forecast accuracy is the most important measure in the process perspective of BSCS. That's why it forms the base of the ISM hierarchy. Supply chain cycle efficiency is the result variable which is the outcome of all efforts made towards process improvements. This measure appears at the top of the hierarchy.

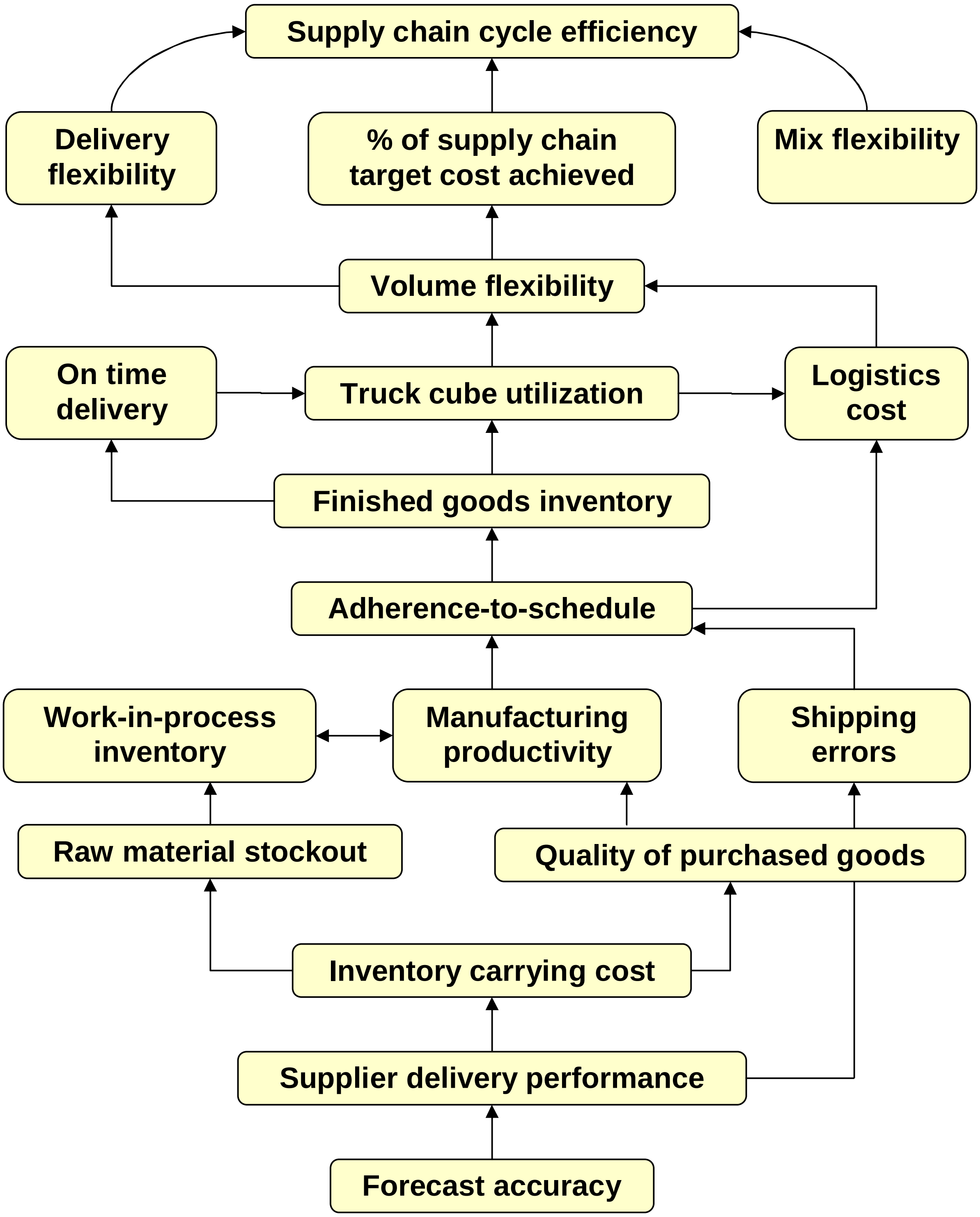


Figure 4.4: The Level Three Framework [$P_2^3(m_i)$]
(among Measures of Process Perspective)

4.7 The Level Three Framework for Customer Perspective, $P_3^3(m_i)$

It is the contextual relationship between **Measures** of the customer perspective. The modeling is carried out for 10 measures identified in this perspective.

Table: 4.25: List of Measures in Customer Perspective

Element No.	Measure Symbol		Measure
1	$^{31}m_1$	:	Customer satisfaction
2	$^{31}m_2$	:	Repeat versus new customer sales
3	$^{31}m_3$	:	Customer perception of quality
4	$^{31}m_4$	:	Customer returns
5	$^{32}m_1$	:	% of resolution on first customer call
6	$^{32}m_2$	:	Order fill rate
7	$^{32}m_3$	:	Order track and trace performance
8	$^{33}m_1$	:	Relative customer order response time
9	$^{33}m_2$	:	Customer response time
10	$^{34}m_1$	:	Market share

The customer perspective shows supply chain measures from the customer's point of view. Number of customer contact points is a measure of service quality that captures how many people the customer has to interact with to be served. The theoretical ideal is a single contact point all the way back through the supply chain. When numerous possible contact points exist at each link in the supply chain, the potential for miscommunication, waste, and delayed response increases exponentially.

Relative customer order response time is a measure that can be used to compare the time it takes one supply chain to respond to a customer order to the rime it takes a competing supply chain to respond to a comparable order. The benchmark used in conjunction with this measure can also be an ambitious world-class standard rather than a competing supply chain. The intent is to ensure that a supply chain does not become isolated from its competitors or unaware of what its customers have come to expect from dealing with world-class companies. The customer perception of flexible response measure can be used to assess how the customer perceives the relationship between customization and response time. The first goal of this survey data would be to determine whether customers feel free to make customized choices regarding their order with respect to packaging, case count, display-ready pallets, product configurations, and so on. The second goal would be to assess whether the customer feels the customized choices are being provided in a timely manner. Customers may feel their desire to customize is thwarted by the supply chain's inability to respond in a timely fashion. (Brewer & Speh, 2000)

4.7.1 Structural Self-Interaction Matrix for $P_3^3(m_i)$

As mentioned before the contextual relationships are identified between any two measures at this level of the proposed Integrated BSCS Framework. For this purpose the meta-research (research about the research) methodology is used which derives conclusion by gathering and interpreting qualitative and quantitative data from various sources. These contextual relationships (CR) are established, based on inferences drawn from surveys, cases, literature review and recent articles in supply chain area. The corresponding Article No. referred for the identification of these relationships is mentioned in Table 4.26.

Table 4.26: Article Reference No. for CR in SSIM for Customer Perspective $P_3^3(m_i)$

		Customer satisfaction 1	Repeat versus new customer sales 2	Customer perception of quality 3	Customer returns 4	% of resolution on first customer call 5	Order fill rate 6	Order track and trace performance 7	Relative customer order response time 8	Customer response time 9	Market share 10
1	Customer satisfaction		A58	A25	A18	A37	A18	A59	A18	A59	A01
2	Repeat versus new customer sales			A37	A18	A67	A06	A03	A25	A65	A65
3	Customer perception of quality				A56	A31	A76	A25	A31	A59	A04
4	Customer returns					A76	A67	A56	A03	A76	A06
5	% of resolution on first customer call						A55	A76	A59	A06	A67
6	Order fill rate							A56	A03	A18	A37
7	Order track and trace performance								A59	A03	A03
8	Relative customer order response time									A67	A67
9	Customer response time										A76
10	Market share										

****A** stands for **Articles and News Clippings** referred.*
See Appendix-C.3 for details of the corresponding Article no. stated here.
*See Appendix-C.2 for **Cases** referred for this perspective.*

For analyzing the measures in the BSCS perspectives, a contextual relationship of "leads to" type is chosen. This means that one element leads to another element. Based on this, contextual relationship between the elements is developed. Keeping in mind the contextual relationship for each measure, the existence of a relation between any two measures (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the measure (i and j):

V: Measure i will help alleviate Measure j;

A: Measure i will be alleviated by Measure j;

X: Measures i and j will help achieve each other; and

O: Measures i and j are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 4.27).

- *Customer Satisfaction* (Measure 1) helps alleviate *Repeat versus new customer sales* (Measure 2). This means that customer will be buying products repeatedly and as well referring it to new customers if they are satisfied. Thus, the relationship between Measures 1 and Measure 2 is denoted by "V" in the SSIM.

- *Order fill rate* (Measure 6) can be alleviated by *Order track and trace performance* (Measure 7), i.e. tracking the orders will help firms to make it possible to meet the orders in time by remedial actions taken on this tracing. Thus, the relationship between these measures is denoted by "A" in the SSIM.

- *Customer Satisfaction* (Measure 1) and *Customer perception of quality* (Measure 3) help achieve each other. Thus, the relationship between these measures is denoted by "X" in the SSIM.

- No relationship exists between *Customer perception of quality* (Measure 3) and *Order fill rate* (Measure 6) and hence the relationship between these measures is denoted by "O" in the SSIM.

Based on similar contextual relationships, the SSIM is developed in Table 4.27 for all the 10 measures identified for this perspective of BSCS.

Table 4.27: SSIM for Measures in Customer Perspective

		Customer satisfaction 1	Repeat versus new customer sales 2	Customer perception of quality 3	Customer returns 4	% of resolution on first customer call 5	Order fill rate 6	Order track and trace performance 7	Relative customer order response time 8	Customer response time 9	Market share 10
1	Customer satisfaction		V	X	A	A	A	A	A	A	V
2	Repeat versus new customer sales			A	A	A	A	A	A	A	V
3	Customer perception of quality				V	A	O	O	O	O	V
4	Customer returns					A	A	O	A	A	V
5	% of resolution on first customer call						V	O	V	V	V
6	Order fill rate							A	V	V	V
7	Order track and trace performance								V	V	V
8	Relative customer order response time									A	V
9	Customer response time										V
10	Market share										

4.7.2 Initial Reachability Matrix for $P_3^3(m_i)$

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

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

- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, initial reachability matrix for the measures is shown in Table 4.28.

Table 4.28: Initial Reachability Matrix for Measures in $P_3^3(m_i)$

		Customer satisfaction	Repeat versus new customer sales	Customer perception of quality	Customer returns	% of resolution on first customer call	Order fill rate	Order track and trace performance	Relative customer order response time	Customer response time	Market share
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**Customer satisfaction**	1	1	1	0	0	0	0	0	0	1
2	**Repeat versus new customer sales**	0	1	0	0	0	0	0	0	0	1
3	**Customer perception of quality**	1	1	1	1	0	0	0	0	0	1
4	**Customer returns**	1	1	0	1	0	0	0	0	0	1
5	**% of resolution on first customer call**	1	1	1	1	1	1	0	1	1	1
6	**Order fill rate**	1	1	0	1	0	1	0	1	1	1
7	**Order track and trace performance**	1	1	0	0	0	1	1	1	1	1
8	**Relative customer order response time**	1	1	0	1	0	0	0	1	0	1
9	**Customer response time**	1	1	0	1	0	0	0	1	1	1
10	**Market share**	0	0	0	0	0	0	0	0	0	1

4.7.3 Final Reachability Matrix for $P_3^3(m_i)$

The final reachability matrix is obtained by incorporating the transitivities as enumerated in Step 4 of the ISM methodology. These transitive links are shown as 1*. In this Table 4.29, the driving power and dependence of each measure are also shown. The driving power of a particular measure is the total number of measures (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it. These driving power and dependencies will be used in the MIC-MAC analysis, where the measures will be classified into five groups of autonomous, dependent, linkage, and independent (driver) and regulating variables

Table 4.29: Final Reachability Matrix for Measures in $P_3^3(m_i)$

		Customer satisfaction	Repeat versus new customer sales	Customer perception of quality	Customer returns	% of resolution on first customer call	Order fill rate	Order track and trace performance	Relative customer order response time	Customer response time	Market share	DRIVING POWER
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
1	**Customer satisfaction**	1	1	1	1*	0	0	0	0	0	1	*5*
2	**Repeat versus new customer sales**	0	1	0	0	0	0	0	0	0	1	*2*
3	**Customer perception of quality**	1	1	1	1	0	0	0	0	0	1	*5*
4	**Customer returns**	1	1	0	1	0	0	0	0	0	1	*4*
5	**% of resolution on first customer call**	1	1	1	1	1	1	0	1	1	1	*9*
6	**Order fill rate**	1	1	1*	1	0	1	0	1	1	1	*8*
7	**Order track and trace performance**	1	1	1*	1*	0	1	1	1	1	1	*9*
8	**Relative customer order response time**	1	1	1*	1	0	0	0	1	0	1	*6*
9	**Customer response time**	1	1	1*	1	0	0	0	1	1	1	*7*
10	**Market share**	0	0	0	0	0	0	0	0	0	1	*1*
DEPENDENCE		*8*	*9*	*7*	*8*	*1*	*3*	*1*	*5*	*4*	*10*	*56*

4.7.4 Level Partitioning of Reachability Matrix for $P_3^3(m_i)$

The reachability and antecedent set for each Measure is found out from final reachability matrix. The reachability set for a particular element consists of the element itself and the other elements, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all elements. The element for which the reachability and the intersection sets are the same is given the top-level element in the ISM hierarchy, which would not help achieve any other element above their own level. After the identification of the top-level element, it is discarded from the other remaining.

Table 4.30: Level Partitioning for Measures in $P_3^3(m_i)$

Iteration 1

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 2, 3, 4, 10	1, 3, 4, 5, 6, 7, 8, 9	1, 3, 4	
2	2, 10	1, 2, 3, 4, 5, 6, 7, 8, 9	2	
3	1, 2, 3, 4, 10	1, 3, 5, 6, 7, 8, 9	1, 3	
4	1, 2, 4, 10	1, 3, 4, 5, 6, 7, 8, 9	1, 4	
5	1, 2, 3, 4, 5, 6, 8, 9, 10	5	5	
6	1, 2, 3, 4, 6, 8, 9, 10	5, 6, 7	6	
7	1, 2, 3, 4, 6, 7, 8, 9, 10	7	7	
8	1, 2, 3, 4, 8, 10	5, 6, 7, 8, 9	8	
9	1, 2, 3, 4, 8, 9, 10	5, 6, 7, 9	9	
10	10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	10	I

Iteration 2

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 2, 3, 4	1, 3, 4, 5, 6, 7, 8, 9	1, 3, 4	
2	2	1, 2, 3, 4, 5, 6, 7, 8, 9	2	II
3	1, 2, 3, 4	1, 3, 5, 6, 7, 8, 9	1, 3	
4	1, 2, 4	1, 3, 4, 5, 6, 7, 8, 9	1, 4	
5	1, 2, 3, 4, 5, 6, 8, 9	5	5	
6	1, 2, 3, 4, 6, 8, 9	5, 6, 7	6	
7	1, 2, 3, 4, 6, 7, 8, 9	7	7	
8	1, 2, 3, 4, 8	5, 6, 7, 8, 9	8	
9	1, 2, 3, 4, 8, 9	5, 6, 7, 9	9	

Iteration 3

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 3, 4	1, 3, 4, 5, 6, 7, 8, 9	1, 3, 4	III
3	1, 3, 4	1, 3, 5, 6, 7, 8, 9	1, 3	
4	1, 4	1, 3, 4, 5, 6, 7, 8, 9	1, 4	III
5	1, 3, 4, 5, 6, 8, 9	5	5	
6	1, 3, 4, 6, 8, 9	5, 6, 7	6	
7	1, 3, 4, 6, 7, 8, 9	7	7	
8	1, 3, 4, 8	5, 6, 7, 8, 9	8	
9	1, 3, 4, 8, 9	5, 6, 7, 9	9	

Iteration 4

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
3	3	3, 5, 6, 7, 8, 9	3	IV
5	3, 5, 6, 8, 9	5	5	
6	3, 6, 8, 9	5, 6, 7	6	
7	3, 6, 7, 8, 9	7	7	
8	3, 8	5, 6, 7, 8, 9	8	
9	3, 8, 9	5, 6, 7, 9	9	

Iteration 5

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
5	5, 6, 8, 9	5	5	
6	6, 8, 9	5, 6, 7	6	
7	6, 7, 8, 9	7	7	

8	8	5, 6, 7, 8, 9	8	V
9	8, 9	5, 6, 7, 9	9	

Iteration 6

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
5	5, 6, 9	5	5	
6	6, 9	5, 6, 7	6	
7	6, 7, 9	7	7	
9	9	5, 6, 7, 9	9	VI

Iteration 7

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
5	5, 6	5	5	
6	6	5, 6, 7	6	VII
7	7	7	7	

Iteration 8

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
5	5	5	5	VIII
7	7	7	7	VIII

Consequently, eight levels are identified for the measures. The relative position of each measure is shown in Table 4.31 by putting it in front of the respective level

Table 4.31: Level of Measures in $P_3^3(m_i)$

LEVEL	ELEMENTS
I	10
II	2
III	1, 4
IV	3
V	8
VI	9
VII	6
VIII	5, 7

4.7.5 Canonical Form of Reachability Matrix for $P_3^3(m_i)$

The Canonical Matrix is developed by clubbing together element in the same level across rows and columns. The resultant matrix shown in below is in canonical form, i.e. with most zero (0) elements in the upper diagonal half of the Matrix and most unitary (1) elements in the lower half.

One of the observations in this canonical matrix is that one inconsistency also exists between variables. One higher level variable is affecting lower level variable. That means lagging variable as determined by ISM methodology is affecting leading variable. This inconsistency is shown in the matrix by highlighting the cell in gray color. The variable Customer satisfaction is affecting variable Customer perception of quality. This is inconsistent, as the level of measure Customer satisfaction is higher than the level of measure Customer perception of quality here. As the primary focus of ISM based model (developed later on) is to determine levels, this inconsistency is not shown in it. This inconsistency is arising mainly due to the limitations of meta-research methodology. Resolution of this inconsistency is the subject of further research.

Table 4.32: Canonical Form of Reachability Matrix for Measures in $P_3^3(m_i)$

		Market share	Repeat versus new customer sales	Customer satisfaction	Customer returns61	Customer perception of quality	Relative customer order response time	Customer response time	Order fill rate	% of resolution on first customer call	Order track and trace performance	LEVEL
		10	**2**	**1**	**4**	**3**	**8**	**9**	**6**	**5**	**7**	
10	**Market share**	1	0	0	0	0	0	0	0	0	0	***I***
2	**Repeat versus new customer sales**	1	1	0	0	0	0	0	0	0	0	***II***
1	**Customer satisfaction**	1	1	1	1*	1	0	0	0	0	0	***III***
4	**Customer returns**	1	1	1	1	0	0	0	0	0	0	***III***
3	**Customer perception of quality**	1	1	1	1	1	0	0	0	0	0	***IV***
8	**Relative customer order response time**	1	1	1	1	1*	1	0	0	0	0	***V***
9	**Customer response time**	1	1	1	1	1*	1	1	0	0	0	***VI***
6	**Order fill rate**	1	1	1	1	1*	1	1	1	0	0	***VII***
5	**% of resolution on first customer call**	1	1	1	1	1	1	1	1	1	0	***VIII***
7	**Order track and trace performance**	1	1	1	1*	1*	1	1	1	0	1	***VIII***
LEVEL		***I***	***II***	***III***	***III***	***IV***	***V***	***VI***	***VII***	***VIII***	***VIII***	

4.7.6 Formation of ISM based Model for $P_3^3(m_i)$

From the final reachability matrix, the structural model is generated. If the relationship exists between the Measures j and i, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model, as shown in Figure 4.5 by replacing element numbers with corresponding measure name. In context to this research it is also The Level Two Framework among measures of Customer Perspective.

It is observed from this figure that % of resolution on first customer call and order track and trace performance are two very important measures in customer perspective of BSCS, and that's why they form the base of the ISM hierarchy. Market share is the outcome of all these efforts to make customer more satisfied. Thus at the top of the hierarchy this measure of market share is actually a result variable.

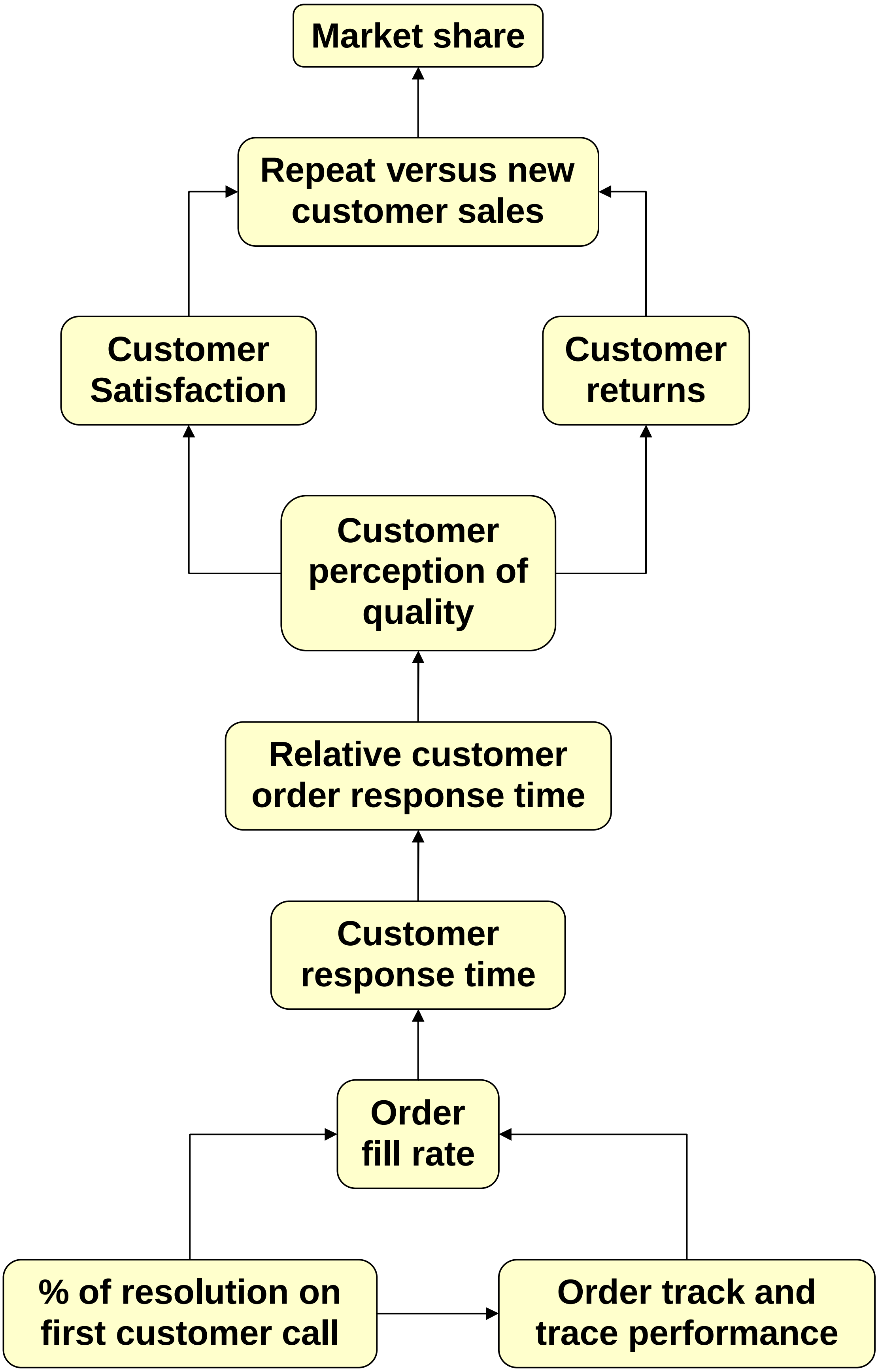


Figure 4.5: The Level Three Framework [$P_3^3(m_i)$]
(among Measures of Customer Perspective)

4.8 The Level Three Framework for Financial Perspective $P_4^3(m_i)$

It is the contextual relationship between **Measures** of the process perspective. The modeling is carried out for 18 measures identified in this perspective.

Table: 4.33: List of Measures in Financial Perspective

Element No.	Measure Symbol		Measure
1	$^{41}m_1$	:	Total revenue
2	$^{41}m_2$	:	Customer sales growth & profitability
3	$^{41}m_3$	:	Total cost
4	$^{42}m_1$	:	Profit
5	$^{42}m_2$	:	Profit margin of supply chain partner
6	$^{43}m_1$	:	Cash flow
7	$^{43}m_2$	:	Cash to cash cycle
8	$^{44}m_1$	:	Return on Investment
9	$^{44}m_2$	:	Return on supply chain assets

Profit margin by supply chain partner captures the percentage of supply chain profits being earned by each supply chain partner. Disproportionately high or low profit percentages for any partner indicates the kind of power imbalance common among companies engaged in arm's- length as opposed to partnership-oriented transactions.

Cash-to-cash cycle is a critical financial measure that ties together several important processes in the supply chain. This cycle is the average rime it takes to convert dollars expended on materials, labor, and so on, into cash in hand. It tells management how long it takes to convert a dollar spent to acquire raw materials into a dollar collected for finished product. Supply chains (hat have successfully increased product and information How and have effectively integrated operations among partners will have faster cash-to-cash cycles than ones that have not done so.

Customer sales growth and profitability measures the sales and profits generated annually by each major customer. This type of report can reveal three major patterns of performance. First, the sales for any one customer should steadily increase each year. Second, the profits earned serving a particular customer should, at a minimum, hold constant on a percentage basis. Preferably, the customer margins earned should increase as the length of the relationship increases. Third, the base of customers served should increase, thereby expanding sales, but each new customer added should be profitable. Unprofitable customer proliferation and sales growth is not beneficial to the supply chain.

The return on supply chain assets is calculated by dividing consumer profitability by the average supply chain assets deployed during the period. The intent is to assess how efficiently the supply chain is coordinating the use of its assets (Brewer & Speh, 2000).

4.8.1 Structural Self-Interaction Matrix for $P_4^3(m_i)$

As mentioned before the contextual relationships are identified between any two measures at this level of the proposed Integrated BSCS Framework. For this purpose the meta-research (research about the research) methodology is used which derives conclusion by gathering and interpreting qualitative and quantitative data from various sources. These contextual relationships (CR) are established, based on inferences drawn from surveys, cases, literature review and recent articles in supply chain area. The corresponding Article No. referred for the identification of these relationships is mentioned in Table 4.34.

Table 4.34: Article Reference No. for CR in SSIM for Financial Perspective $P_4^3(m_i)$

		Total revenue 1	Customer sales growth & profitability 2	Total cost 3	Profit (Total revenue less total cost) 4	Profit margin of supply chain partner 5	Cash flow 6	Cash to cash cycle 7	Return on Investment 8	Return on supply chain assets 9
1	Total revenue		A27	A63	A51	A13	A51	A28	A15	A34
2	Customer sales growth & profitability			A63	A32	A27	A05	A63	A24	A35
3	Total cost				A74	A74	A07	A24	A26	A74
4	Profit					A74	A74	A63	A24	A35
5	Profit margin of supply chain partner						A71	A51	A74	A35
6	Cash flow							A51	A63	A26
7	Cash to cash cycle								A63	A26
8	Return on Investment									A74
9	Return on supply chain assets									

****A** stands for **Articles and News Clippings** referred.*
See Appendix-C.3 for details of the corresponding Article no. stated here.
*See Appendix-C.2 for **Cases** referred for this perspective.*

For analyzing the measures in the BSCS perspectives, a contextual relationship of "leads to" type is chosen. This means that one element leads to another element. Based on this, contextual relationship between the elements is developed. Keeping in mind the contextual relationship for each measure, the existence of a relation between any two measures (i and

j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the measure (i and j):

V: Measure i will help alleviate Measure j;

A: Measure i will be alleviated by Measure j;

X: Measures i and j will help achieve each other;

O: Measures i and j are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 4.35).

- *Total cost* (Measure 3) helps alleviate *Profit* (Measure 4). This means that as efforts are made to save cost by applying cost effective efforts, profit will improve. Thus, the relationship between Measures 3 and Measure 4 is denoted by "V" in the SSIM.

Table 4.35: SSIM for Measures in Financial Perspective

		Total revenue 1	Customer sales growth & profitability 2	Total cost 3	Profit (Total revenue less total cost) 4	Profit margin of supply chain partner 5	Cash flow 6	Cash to cash cycle 7	Return on Investment 8	Return on supply chain assets 9
1	**Total revenue**		A	A	V	V	V	A	A	A
2	**Customer sales growth & profitability**			A	V	V	V	A	O	A
3	**Total cost**				V	V	V	V	A	A
4	**Profit**					A	A	A	A	A
5	**Profit margin of supply chain partner**						A	A	A	A
6	**Cash flow**							A	A	A
7	**Cash to cash cycle**								A	A
8	**Return on Investment**									X
9	**Return on supply chain assets**									

- *Profit margin of supply chain partner* (Measure 5) can be alleviated by *Return on supply chain assets* (Measure 9), i.e. if assets are utilized in the perspective of whole supply chain the partners will be getting more profit margins. Thus, the relationship between these measures is denoted by "A" in the SSIM.

- *Return on Investment* (Measure 8) and *Return on supply chain assets* (Measure 9) help achieve each other. Thus, the relationship between these measures is denoted by "X" in the SSIM.

- No relationship exists between *Customer sales growth & profitability* (Measure 2) and *Return on Investment* (Measure 8) and hence the relationship between these measures is denoted by "O" in the SSIM.

Based on similar contextual relationships, the SSIM is developed in Table 4.35 for all the 9 measures identified for this perspective of BSCS.

4.8.2 Initial Reachability Matrix for $P_4^3(m_i)$

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

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

Table 4.36: Initial Reachability Matrix for Measures in $P_4^3(m_i)$

		Total revenue	Customer sales growth & profitability	Total cost	Profit (Total revenue less total cost)	Profit margin of supply chain partner	Cash flow	Cash to cash cycle	Return on Investment	Return on supply chain assets
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	**Total revenue**	1	0	0	1	1	1	0	0	0
2	**Customer sales growth & profitability**	1	1	0	1	1	1	0	0	0
3	**Total cost**	1	1	1	1	1	1	1	0	0
4	**Profit**	0	0	0	1	0	0	0	0	0
5	**Profit margin of supply chain partner**	0	0	0	1	1	0	0	0	0
6	**Cash flow**	0	0	0	1	1	1	0	0	0
7	**Cash to cash cycle**	1	1	0	1	1	1	1	0	0
8	**Return on Investment**	1	0	1	1	1	1	1	1	1
9	**Return on supply chain assets**	1	1	1	1	1	1	1	1	1

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

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

Following these rules, initial reachability matrix for the measures is shown in Table 4.36

4.8.3 Final Reachability Matrix for $P_4^3(m_i)$

The final reachability matrix is obtained by incorporating the transitivities as enumerated in Step 4 of the ISM methodology. These transitive links are shown as 1*. In this Table 4.37, the driving power and dependence of each measure are also shown. The driving power of a particular measure is the total number of measures (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it. These driving power and dependencies will be used in the MICMAC analysis, where the measures will be classified into five groups of autonomous, dependent, linkage, and independent (driver) and regulating variables

Table 4.37: Final Reachability Matrix for Measures in $P_4^3(m_i)$

		Total revenue	Customer sales growth & profitability	Total cost	Profit (Total revenue less total cost)	Profit margin of supply chain partner	Cash flow	Cash to cash cycle	Return on Investment	Return on supply chain assets	DRIVING POWER
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
1	**Total revenue**	1	0	0	1	1	1	0	0	0	***4***
2	**Customer sales growth & profitability**	1	1	0	1	1	1	0	0	0	***5***
3	**Total cost**	1	1	1	1	1	1	1	0	0	***7***
4	**Profit**	0	0	0	1	0	0	0	0	0	***1***
5	**Profit margin of supply chain partner**	0	0	0	1	1	0	0	0	0	***2***
6	**Cash flow**	0	0	0	1	1	1	0	0	0	***3***
7	**Cash to cash cycle**	1	1	0	1	1	1	1	0	0	***6***
8	**Return on Investment**	1	1*	1	1	1	1	1	1	1	***9***
9	**Return on supply chain assets**	1	1	1	1	1	1	1	1	1	***9***
DEPENDENCE		***6***	***5***	***3***	***9***	***8***	***7***	***3***	***2***	***2***	***46***

4.8.4 Level Partitioning of Reachability Matrix for $P_4^3(m_i)$

The reachability and antecedent set for each Measure is found out from final reachability matrix. The reachability set for a particular element consists of the element itself and the other elements, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all elements. The element for which the reachability and the intersection sets are the same is given the top-level element in the ISM hierarchy, which would not help achieve any other element above their own level. After the identification of the top-level element, it is discarded from the other remaining.

Table 4.38: Level Partitioning for Measures in $P_4^3(m_i)$

Iteration 1

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 4, 5, 6	1, 2, 3, 7, 8, 9	1	
2	1, 2, 4, 5, 6	2, 3, 7, 8, 9	2	
3	1, 2, 3, 4, 5, 6, 7	3, 8, 9	3	
4	4	1, 2, 3, 4, 5, 6, 7, 8, 9	4	I
5	4, 5	1, 2, 3, 5, 6, 7, 8, 9	5	
6	4, 5, 6	1, 2, 3, 6, 7, 8, 9	6	
7	1, 2, 4, 5, 6, 7	3, 7, 8, 9	7	
8	1, 2, 3, 4, 5, 6, 7, 8, 9	8, 9	8, 9	
9	1, 2, 3, 4, 5, 6, 7, 8, 9	8, 9	8, 9	

Iteration 2

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 5, 6	1, 2, 3, 7, 8, 9	1	
2	1, 2, 5, 6	2, 3, 7, 8, 9	2	
3	1, 2, 3, 5, 6, 7	3, 8, 9	3	
5	5	1, 2, 3, 5, 6, 7, 8, 9	5	II
6	5, 6	1, 2, 3, 6, 7, 8, 9	6	
7	1, 2, 5, 6, 7	3, 7, 8, 9	7, 8	
8	1, 2, 3, 5, 6, 7, 8, 9	8, 9	8, 9	
9	1, 2, 3, 5, 6, 7, 8, 9	8, 9	8, 9	

Iteration 3

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1, 6	1, 2, 3, 7, 8, 9	1	
2	1, 2, 6	2, 3, 7, 8, 9	2	
3	1, 2, 3, 6, 7	3, 8, 9	3	
6	6	1, 2, 3, 6, 7, 8, 9	6	III
7	1, 2, 6, 7	3, 7, 8, 9	7	
8	1, 2, 3, 6, 7, 8, 9	8, 9	8, 9	
9	1, 2, 3, 6, 7, 8, 9	8, 9	8, 9	

Iteration 4

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
1	1	1, 2, 3, 7, 8, 9	1	IV
2	1, 2	2, 3, 7, 8, 9	2	
3	1, 2, 3, 7	3, 8, 9	3	
7	1, 2, 7	3, 7, 8, 9	7	

8	1, 2, 3, 7, 8, 9	8, 9	8, 9	
9	1, 2, 3, 7, 8, 9	8, 9	8, 9	

Iteration 5

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
2	2	2, 3, 7, 8, 9	2	V
3	2, 3, 7	3, 8, 9	3	
7	2, 7	3, 7, 8, 9	7	
8	2, 3, 7, 8, 9	8, 9	8, 9	
9	2, 3, 7, 8, 9	8, 9	8, 9	

Iteration 6

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
3	3, 7	3, 8, 9	3	
7	7	3, 7, 8, 9	7	VI
8	3, 7, 8, 9	8, 9	8, 9	
9	3, 7, 8, 9	8, 9	8, 9	

Iteration 7

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
3	3	3, 8, 9	3	VII
8	3, 8, 9	8, 9	8, 9	
9	3, 8, 9	8, 9	8, 9	

Iteration 8

El. E_i	Reachability Set R (E_i)	Antecedent Set A (E_i)	Intersection Set (R∩A)	Level
8	8, 9	8, 9	8, 9	VIII
9	8, 9	8, 9	8, 9	VIII

Consequently, seven levels are identified for the measures. The relative position of each measure is shown in Table 4.39 by putting it in front of the respective level

Table 4.39: Level of Measures in $P_4^3(m_i)$

LEVEL	ELEMENTS
I	4
II	5
III	6
IV	1
V	2
VI	7
VII	3
VIII	8, 9

4.8.5 Canonical Form of Reachability Matrix for $P_4^3(m_i)$

The Canonical Matrix is developed by clubbing together element in the same level across rows and columns. The resultant matrix shown in below is in canonical form, i.e. with most zero (0) elements in the upper diagonal half of the Matrix and most unitary (1) elements in the lower half.

Table 4.40: Canonical Form of Reachability Matrix for Measures in $P_4^3(m_i)$

		Profit (Total revenue less total cost)	Profit margin of supply chain partner	Cash flow	Total revenue	Customer sales growth & profitability	Cash to cash cycle	Total cost	Return on Investment	Return on supply chain assets	LEVEL
		4	**5**	**6**	**1**	**2**	**7**	**3**	**8**	**9**	
4	**Profit**	1	0	0	0	0	0	0	0	0	***I***
5	**Profit margin of supply chain partner**	1	1	0	0	0	0	0	0	0	***II***
6	**Cash flow**	1	1	1	0	0	0	0	0	0	***III***
1	**Total revenue**	1	1	1	1	0	0	0	0	0	***IV***
2	**Customer sales growth & profitability**	1	1	1	1	1	0	0	0	0	***V***
7	**Cash to cash cycle**	1	1	1	1	1	1	0	0	0	***VI***
3	**Total cost**	1	1	1	1	1	1	1	0	0	***VII***
8	**Return on Investment**	1	1	1	1	1*	1	1	1	1	***VIII***
9	**Return on supply chain assets**	1	1	1	1	1	1	1	1	1	***VIII***
LEVEL		***I***	***II***	***III***	***IV***	***V***	***VI***	***VII***	***VIII***	***VIII***	

4.8.6 Formation of ISM based Model for $P_4^3(m_i)$

From the final reachability matrix, the structural model is generated. If the relationship exists between the measure I and j, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model, as shown in Figure 4.6 by replacing element numbers with corresponding /measure name. In context to this research it is also The Level Three Framework among measures of Financial Perspective.

It is observed from this figure that return on supply chain assets and return on investment are two very important financial measures which are forming the base of the ISM hierarchy. Profit is the reflection of all financial implications done in the entire supply chain and that is the reason this measure is at the top of the hierarchy.

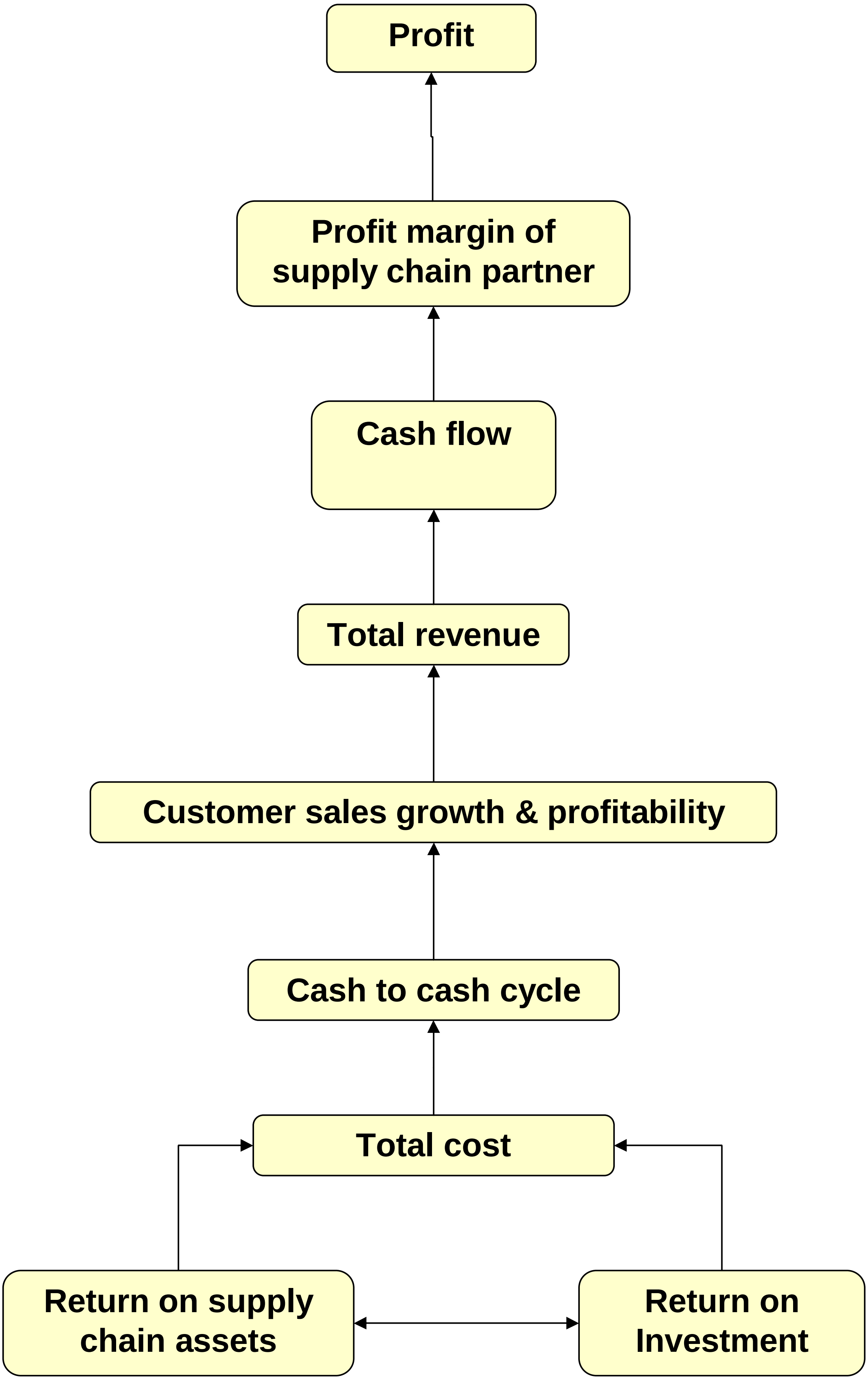


Figure 4.6: The Level Three Framework [$P_4^3(m_i)$]
(among Measures of Financial Perspective)

4.9 The Level Three Framework (Combined), $P_c^3(m_i)$

It is the contextual relationship between **Measures** of all the perspectives taken combinedly and modeling all m_i of all Perspectives. These total 53 measures are identified in Table 4.41

Table: 4.41: List of all Measures from all Four Perspectives

Element No.	Measure Symbol		Measure
1	$^{11}m_1$	:	Product finalization point
2	$^{11}m_2$	:	Personnel with related certificates
3	$^{11}m_3$	:	Training on SCM
4	$^{11}m_4$	:	% of sales from new product
5	$^{11}m_5$	:	New product time-to-market
6	$^{12}m_1$	:	R&D Investment
7	$^{12}m_2$	:	Product category commitment ratio
8	$^{12}m_3$	:	VMI & CRP ratio
9	$^{12}m_4$	:	Trust with customer
10	$^{12}m_5$	:	Trust with supplier
11	$^{12}m_6$	:	Supplier development and evaluation system
12	$^{13}m_1$	:	% of shared data sets
13	$^{13}m_2$	:	EDI transactions
14	$^{13}m_3$	:	% of customer sharing forecast
15	$^{13}m_4$	:	% of supplier sharing forecast
16	$^{14}m_1$	:	Performance trajectories of competing technologies
17	$^{21}m_1$	:	Forecast accuracy
18	$^{21}m_2$	:	Supply chain cycle efficiency
19	$^{21}m_3$	:	Volume flexibility
20	$^{21}m_4$	:	Delivery flexibility
21	$^{21}m_5$	:	Mix flexibility
22	$^{21}m_6$	:	% of supply chain target cost achieved
23	$^{21}m_7$	:	Inventory carrying cost
24	$^{22}m_1$	:	Supplier delivery performance
25	$^{22}m_2$	:	Quality of purchased goods
26	$^{22}m_3$	:	Raw material stockout
27	$^{22}m_4$	:	Manufacturing productivity
28	$^{22}m_5$	:	Work-in-process inventory
29	$^{22}m_6$	:	Adherence-to-schedule
30	$^{23}m_1$	:	Finished goods inventory
31	$^{23}m_2$	:	On time delivery
32	$^{23}m_3$	:	Shipping errors

Element No.	Measure Symbol		Measure
33	$^{23}m_4$	:	Truck cube utilization
34	$^{23}m_5$	:	Logistics cost
35	$^{31}m_1$	:	Customer satisfaction
36	$^{31}m_2$	:	Repeat versus new customer sales
37	$^{31}m_3$	:	Customer perception of quality
38	$^{31}m_4$	:	Customer returns
39	$^{32}m_1$	:	% of resolution on first customer call
40	$^{32}m_2$	:	Order fill rate
41	$^{32}m_3$	:	Order track and trace performance
42	$^{33}m_1$	:	Relative customer order response time
43	$^{33}m_2$	:	Customer response time
44	$^{34}m_1$	:	Market share
45	$^{41}m_1$	:	Total revenue
46	$^{41}m_2$	:	Customer sales growth & profitability
47	$^{41}m_3$	:	Total cost
48	$^{42}m_1$	:	Profit
49	$^{42}m_2$	:	Profit margin of supply chain partner
50	$^{43}m_1$	:	Cash flow
51	$^{43}m_2$	:	Cash to cash cycle
52	$^{44}m_1$	:	Return on Investment
53	$^{44}m_2$	:	Return on supply chain assets

4.9.1 Structural Self-Interaction Matrix for $P_c^3(m_i)$

As mentioned before the contextual relationship is identified between any two measures at this level of proposed Integrated BSCS Framework. For this purpose the meta-research (research about the research) methodology is used which derives conclusion by gathering and interpreting qualitative and quantitative data from various sources. These contextual relationships (CR) are established, based on inferences drawn from surveys, cases, literature review and recent articles in supply chain area. The corresponding sources referred for the identification of these relationships are mentioned in Table 4.42. In this table A stands for Articles and News Clippings referred, S stands for Surveys referred and C stands for Cases referred. See Appendix-C.1 for details of the corresponding source no. stated in the table.

For analyzing the measures in the BSCS perspectives, a contextual relationship of “leads to” type is chosen. This means that one element leads to another element. Based on this, contextual relationship between the elements is developed. Keeping in mind the contextual relationship for each measure, the existence of a relation between any two measures (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the measure (i and j):

V: Measure i will help alleviate Measure j;

A: Measure i will be alleviated by Measure j;

X: Measures i and j will help achieve each other; and

O: Measures i and j are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 4.43).

- *Trust with supplier* (Measure 10) helps alleviate *% of supplier sharing forecast* (Measure 15). This means that as trust is built with suppliers, they tend to share forecast more. Thus, the relationship between Measures 10 and Measure 15 is denoted by "V" in the SSIM.
- *Inventory carrying cost* (Measure 23) can be alleviated by *Supplier delivery performance* (Measure 24), i.e. inventory carrying cost will be very much reduced if supplier delivers materials at the required time in right quantity. Thus, the relationship between these measures is denoted by "A" in the SSIM.
- *Customer Satisfaction* (Measure 35) and *Customer perception of quality* (Measure 37) help achieve each other. Thus, the relationship between these measures is denoted by "X" in the SSIM.
- No relationship exists between *Finished goods inventory* (Measure 30) and *Shipping errors* (Measure 32) and hence the relationship between these measures is denoted by "O" in the SSIM.

Based on similar contextual relationships, the SSIM is developed in Table 4.43 for all the 53 measures of all the perspectives of BSCS.

4.9.2 Initial Reachability Matrix for $P_c^3(m_i)$

The SSIM is transformed into a binary matrix, called the initial reachability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

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

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

Following these rules, initial reachability matrix for the measures is shown in Table 4.44.

4.9.3 Final Reachability Matrix for $P_c^3(m_i)$

The final reachability matrix is obtained by incorporating the transitivities as enumerated in Step 4 of the ISM methodology. These transitive links are shown as 1*. In this Table 4.45, the driving power and dependence of each measure are also shown. The driving power of a particular measure is the total number of measures (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it. These driving power and dependencies will be used in the MICMAC analysis, where the measures will be classified into five groups of autonomous, dependent, linkage, and independent (driver) and regulating variables.

4.9.4 Level Partitioning of Reachability Matrix for $P_c^3(m_i)$

The reachability and antecedent set for each measure is found out from final reachability matrix. The reachability set for a particular element consists of the element itself and the other elements, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all elements. The element for which the reachability and the intersection sets are the same is given the top-level element in the ISM hierarchy, which would not help achieve any other element above their own level. After the identification of the top-level element, it is discarded from the other remaining. Only Iteration1 is shown in Table 4.46.

Consequently, thirty levels are identified for the measures. The relative position of each measure is shown in Table 4.47 by putting it in front of the respective level.

Table 4.47: Level of Measures in $P_c^3(m_i)$

LEVEL	ELEMENTS
I	48
II	49, 50
III	45
IV	46, 44
V	51
VI	47
VII	52
VIII	1, 53, 36
IX	4, 18, 22
X	35, 38
XI	37
XII	5, 16, 42
XIII	7
XIV	21, 43
XV	19, 20, 40
XVI	34
XVII	31, 39, 41
XVIII	30, 33
XIX	29
XX	27, 28, 32
XXI	25, 26
XXII	23
XXIII	24
XXIV	6, 8, 17
XXV	11, 15
XXVI	14
XXVII	12
XXVIII	9, 10, 13
XXIX	2
XXX	3

4.9.6 Formation of ISM based Model for $P_c^3(m_i)$

From the final reachability matrix, the structural model is generated. If the relationship exists between the Measures j and i, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model as shown in the Figure 4.7 by replacing element numbers with corresponding measure name. In context to this research it is also The Level Three Framework (Combined) between measures of all four perspectives.

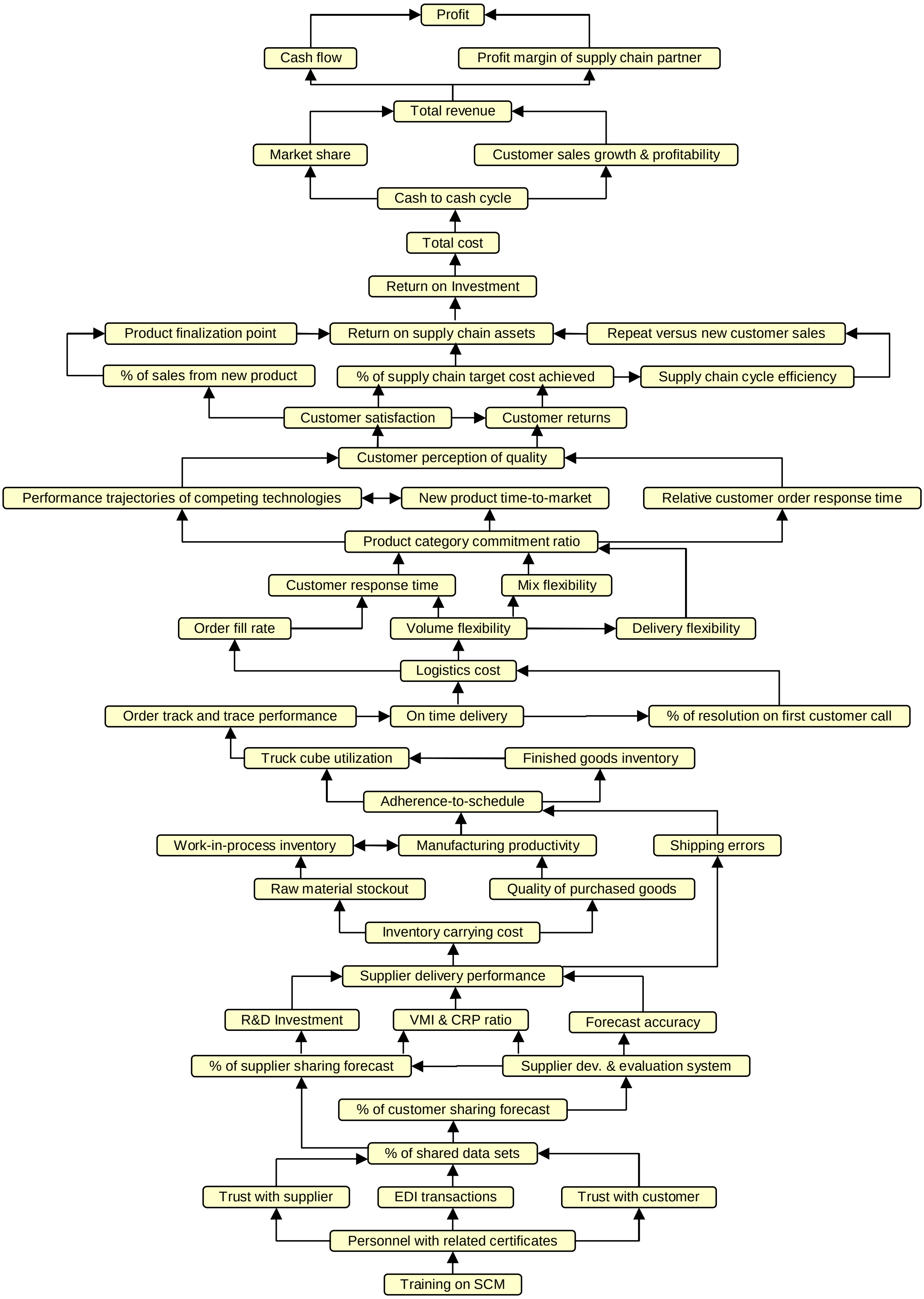


Figure 4.7: The Level Three Framework (Combined) [$P_c^3(m_i)$]
(among Measures of All Perspectives)

Based on these six ISM based models, the three tier Integrated BSCS can be constructed as shown below:

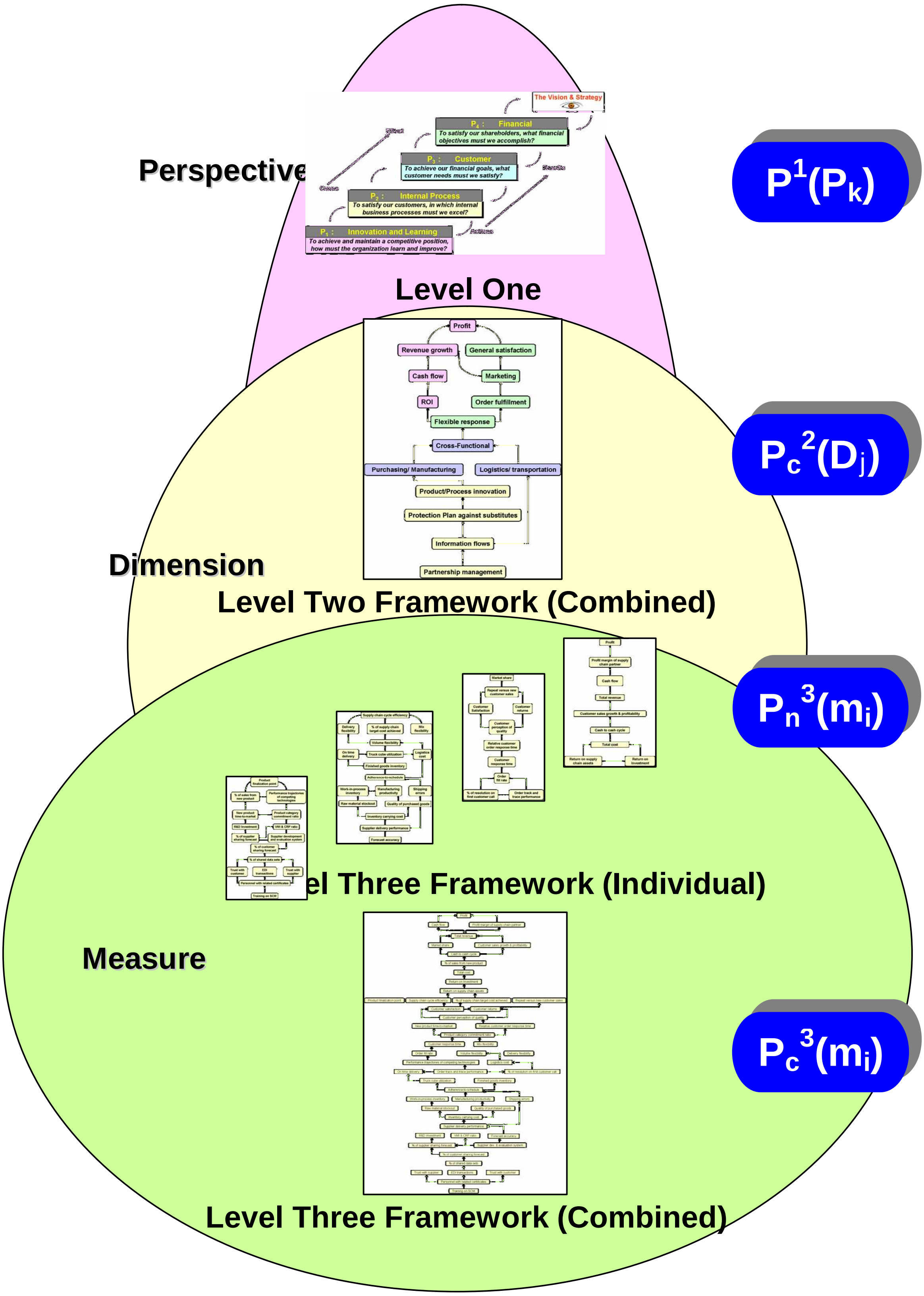


Figure 4.8: Integrated Three Level Balanced Supply Chain Scorecard Framework

Chapter – 5

Analysis and Managerial Implications

This chapter is divided into three sections. In the first section an attempt is made to validate the framework developed through expert opinion survey. In the second section an analysis is made for variables (measures/dimensions) on the basis of MICMAC analysis, which divides all the variables in five categories according to their driving power (the degree to which it affects other variables) and dependence power(the degree to which it is affected by other variables). In the third section an attempt is made for comparative analysis of the newly developed framework with measure's orientation in SCOR Model (customer facing, Internal Facing and Shareholder facing) and with transformation dimensionality of measures in Beamon's R-O-F Model (resource, output and flexibility measures). The comparison is done at the Level Three Framework (Combined) for the new model. The results thus got seem to verify the structure of the developed framework.

5.1 Validation of Framework(s)

Expert opinion survey technique was applied for the validation of the framework developed in the previous chapter. Altogether thirty three experts (Managers in-charge of supply chain management in various industries and the consultants in the supply chain management field) were asked to comment on the models developed. The ISM models were sent to them through e-mail and they were requested to comment about each Contextual Relationship (CR) in that model. The contextual relationships were numbered in each model to make suggestion specific and to the point. Total four experts replied back out of which two were from the organizations providing solutions for supply chain and two were from the industry.

All experts were at senior manager level and having relevant experience in the field. In general their responses were:

- Most of the Contextual Relationships in these models are valid and pertinent to the perspective.
- Measures used in these models are generic and covers all parts of SCM.
- Few specific comments received are discussed later on for further improvement in these frameworks.
- Some measures must be specified more precisely.
- Few Contextual Relationships are product, industry and policy specific and may be inapplicable in those situations.

Hence overall, the model, its contextual relationships and the hierarchy in which measure seems to be are valid and can be used for measuring supply chain performance. The appropriate perspective must be chosen for managerial interventions so that overall objectives of organizations are aligned to that of supply chain.

5.2 MICMAC Analysis

The *Matrice d'Impacts Croisés Multiplication Appliquée à un Classement* (MICMAC) or *Cross-Impact Matrix Multiplication Applied to Classification* establishes a connection between all the elements that constitute a system (Godet, 1993). It enables the study of the direct links among the variables. The aim of the MICMAC is to find the key variables of the system studying the influence, both direct and indirect, among all the variables (Arcade et al., 1999). In reality, beyond the direct links, indirect links do also exist among the variables. Chains of influence and feedback loops activate these links. A very simple matrix composed of several variables can contain millions of interactions in the form of chains and loops.

The human brain cannot imagine and cannot interpret such a complex net of relationships. The MICMAC methodology, which uses the properties of graphs applied to the structural matrix, facilitates the study of the diffusion of impacts through the chains and loops of retroaction. The use of the MICMAC allows the ranking of variables according to their driving power (the degree to which it affects other variables) and dependency (the degree to which it is affected by other variables). It is possible to detect that, from a certain order of power of the matrix, the hierarchy remains stable (Ritchie, 1997).

It helps to determine relationships between a given set of variables in a "system" in order to identify those, which have the strongest impact on the system as a whole (key factors). The strength of the MICMAC application lies in identifying variables of indirect importance and particularly those, which are likely to elude the analyst (Coates, 2000). The tool is often used as a starting point for a logical sequence of work in futures studies to define a coherent framework for expert inquiries and for the final scenario building process.

5.2.1 Driving Power x Dependency Graph

Based on the driving power and dependence power, as calculated in the final reachability matrix of each structural model, a graph can be plotted between dependence and driving power. The cloud of points' repartition in the Driving power x Dependency plane and, in particular, with respect to the various frames set around their centre of gravity, allows the determination of five categories of variables. These categories differ from each other depending on the specific role that the variables they include can play in the dynamics of the system (Arcade, 1999). Variable categories in this graph are shown in Figure 5.1.

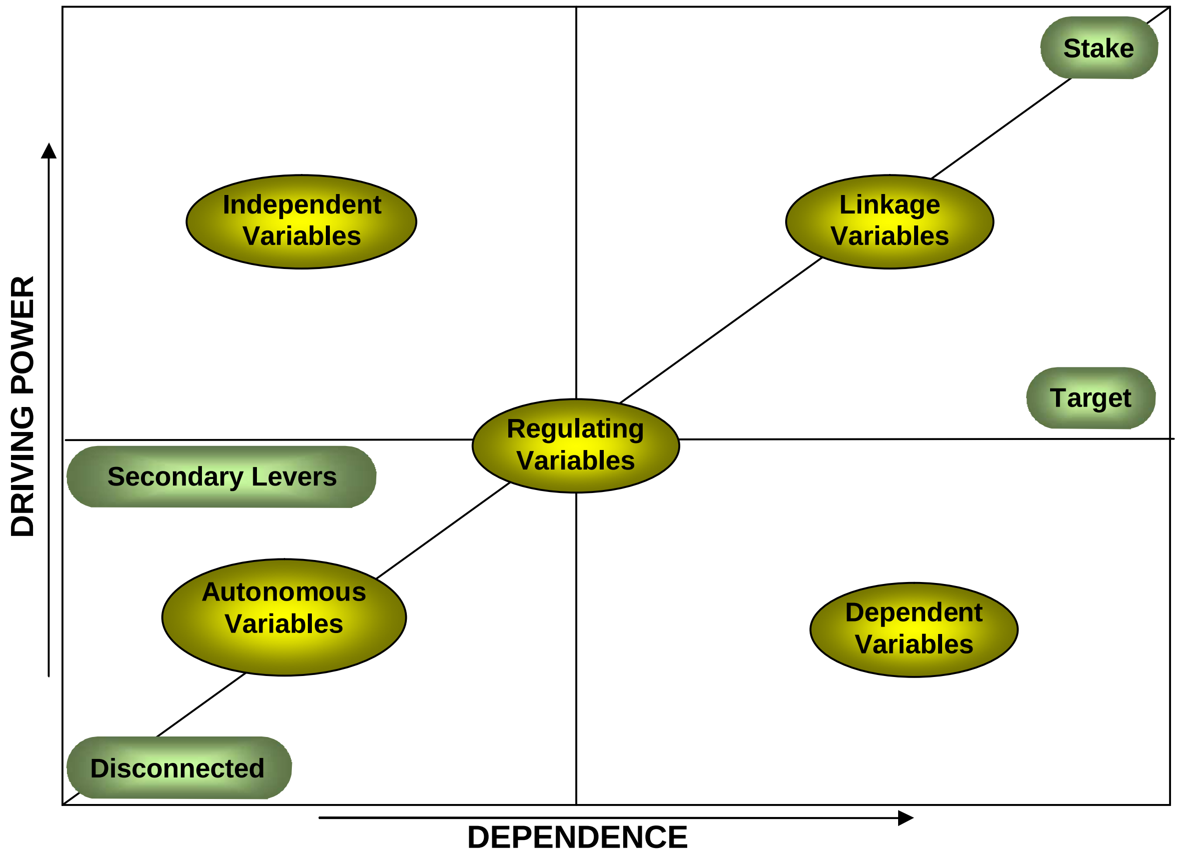


Figure 5.1: Driving Power X Dependence Graph for MICMAC Analysis

Table 5.1 describes each of these categories with relevant managerial implications drawn. The variables in each category are having certain characteristic, which make them crucial for understanding system behavior and stability (Godet, 1997).

Table 5.1: Different Variables in Driving Power X Dependence Graph

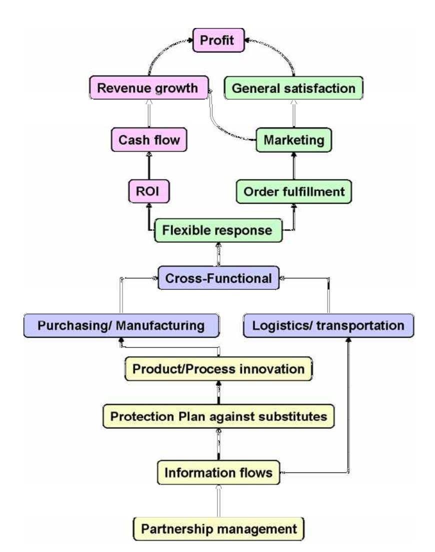
Independent or "Driving" Variables
These variables are, altogether, very driving and only slightly dependent. Most of the system thus depends on those variables located in the northwest frame of the chart. The driving variables are its most crucial elements since they can act on the system depending on how much we can control them as a key factor either of inertia or of movement. They are also considered as entry variables in the system. Among them, there are most often environment variables, which strongly condition the system, but in general cannot be controlled by it.
Linkage or "Relay" Variables
They are at the same time very driving and very dependent. These variables, situated in the northeast frame of the chart, are by nature factors of instability since any action on them has consequences on the other variables in the event certain conditions on other driving variables are met. But these consequences can have a boomerang effect, which either amplifies or forestalls the initial impulse. It is also possible to distinguish, within this group, between: **Stake Variables**, more precisely located around the diagonal, which will have strong possibilities to stimulate the major actors, since, given their unstable character, they are a potential breakpoint for the system; **Target Variables**, situated under the diagonal rather than along the eastwest frontier, are rather more dependent than driving. Therefore, they can be considered, to a certain extent, as resulting from the system's evolution. However, a willful action can be conducted on them so as to make them evolve in the desired way. Thus, they represent possible objectives for the system in its entirety, rather than wholly predetermined consequences.
Dependent or "Result" Variables
These variables, located in the southeast frame of the chart, are at the same time barely influent and very dependent. So, they are especially sensitive to the evolution of driving variables and/or relay variables. They are the "output" variables of the system.
Autonomous or "Excluded" Variables
They are barely influent or dependent. These variables are situated in the southwest frame, and appear relatively out of line with the system since they neither halt a major evolution undergone by the system, nor really take advantage of it. A distinction must be drawn within this group between: **Disconnected Variables**, situated near the axis's origin, whose evolution therefore seems to be rather excluded from the global dynamics of the system; **Secondary Levers**, which, although quite autonomous, are more independent than dependent. Variables concerned are located in the southeast frame, to a certain extent above the diagonal, and can be used as secondary acting variables or as application points for possible accompanying measures.
Regulating Variables
One final type of variable merits being mentioned, less so for its intrinsic definition than for its original situation with regard to the other types presented above. These are the regulating variables, situated mostly in the centre of gravity of the system. They can successively act at times as secondary levers, as weak objectives, or as secondary stakes. They may be helpful for achieving strategic objectives, although their influence on the system is not decisive.

The purpose of plotting this graph is to see the clustering of variables in these five categories, so that variables which are strategic in nature and variables which are most critical for achievement of these strategic objectives can be identified. This identification is of utmost importance for practicing managers, as they will then be able to utilize and align their resources likewise. The other purpose of this plot is to identify stability of the system as whole also. If majority of the variables is aligned to the diagonal of autonomous and linkage variables, the system is unstable, otherwise if they are clustered in L shape in three categories namely, independent, autonomous and dependent, then system is stable.

For the MICMAC analysis in each framework developed in previous chapter, the elements are clustered only in five broad variable categories. The stake, target, secondary lever and disconnected variables are left out from the analysis.

5.3 MICMAC Analysis for Dimensions of The Level Two Framework $P_c^2(D_j)$

From the final reachability matrix in the Table 4.4, the driving power and dependence of each dimension is plotted on the Driving power x Dependence graph as shown below.



No.		Dimension
1	:	Revenue growth
2	:	Profit
3	:	Cash flow
4	:	ROI
5	:	General satisfaction
6	:	Order fulfillment
7	:	Flexible response
8	:	Marketing
9	:	Cross-Functional
10	:	Purchasing/ Manufacturing
11	:	Logistics/ transportation
12	:	Product/Process innovation
13	:	Partnership management
14	:	Information flows
15	:	Protection Plan against substitutes

DRIVING POWER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	Independent (Driver) Variables									Linkage Variables					
14	13	14													
13															
12		15													
11				12											
10			11		10										
9							9								
8								7							
7					Regulating Variables				6						
6															
5										4, 5					
4												8			
3													3		
2															
1	Autonomous Variables									Dependent Variables				1	2

DEPENDENCE

Figure 5.2: Driving Power x Dependence Graph for All Dimensions in $P_c^2(D_j)$

The driving power of a particular dimension is the total number of dimensions (including itself) which it may help achieve. The dependence is the total number of dimensions which may help achieving it.

Managerial Implications:

Analyzing this graph and the framework $P_c^2(D_j)$ draws very crucial conclusion for the practicing managers about the characteristics of variables. The driving power-dependence graph (Figure 5.2) gives some valuable insights about the relative importance and interdependencies among the dimensions of BSCS for performance measurement. The *managerial implications* emerging from this framework and graph are as follows:

- The driving power dependence diagram indicates that independent variables of SCPM such as *Logistics/ transportation, Product/Process innovation, Partnership management, Information flows, Protection Plan against substitutes* are at the bottom of the ISM hierarchy having greater driving power. Thus the management needs to address these enabler variables more carefully in the supply chains. It can be seen that these variables help to achieve the desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that management should devise strategies to enhance the deployment of independent variables so that the productivity and performance are improved.

- *Revenue growth, General satisfaction, Profit, Cash flow, ROI and Marketing* are weak drivers but strongly dependent on other variables. They are seen at the top of the ISM hierarchy. These variables represent the desired objectives of the SCPM system.

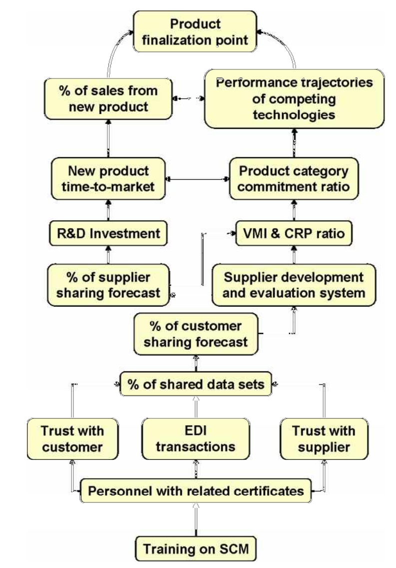
- No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Thus, it can be inferred that among all the 15 variables chosen in this study, no variable is unstable.

- No variable is seen as a autonomous variable that has a weak driving power as well as weak dependence. Thus there is no such variable which is isolated from the system.

- The driving power-dependence graph indicates that *Order fulfillment, Flexible response, and Cross-Functional* are the regulating variables for the enhancement of productivity and performance of supply chain. These enabler variables appear as moderate driver as well as moderate dependent. They may be helpful for achieving strategic objectives, although their influence on the system is not decisive.

5.4 MICMAC Analysis for The Level Three Framework of Innovation and Learning Perspective, $P_1^3(m_i)$

From the final reachability matrix in the Table 4.11, the driving power and dependence of each dimension is plotted on the Driving power x Dependence graph as shown below.



No.		Dimension
1	:	Product finalization point
2	:	Personnel with related certificates
3	:	Training on SCM
4	:	% of sales from new product
5	:	New product time-to-market
6	:	R&D Investment
7	:	Product category commitment ratio
8	:	VMI & CRP ratio
9	:	Trust with customer
10	:	Trust with supplier
11	:	Supplier development & eval. system
12	:	% of shared data sets
13	:	EDI transactions
14	:	% of customer sharing forecast
15	:	% of supplier sharing forecast
16	:	Performance trajectories of competing technologies

DRIVING POWER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16			Independent (Driver) Variables								Linkage Variables					
15	3															
14		2														
13																
12	13				10											
11			9			12										
10																
9							14	15								
8					Regulating Variables					8, 11						
7																
6										6						
5														5, 7	4	
4																
3													16			
2																
1	Autonomous Variables								Dependent Variables						1	

DEPENDENCE

Figure 5.3: Driving Power x Dependence Graph for Measures in $P_1^3(m_i)$

The driving power of a particular measure is the total number of measures (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it.

Managerial Implications:

Analyzing this graph and the framework $P_1^3(m_i)$ draws very crucial conclusions for the practicing managers about the characteristics of variables. The driving power-dependence graph (Figure 5.3) gives some valuable insights about the relative importance and interdependencies among the measures of Innovation and Learning Perspective of the BSCS. The managerial implications emerging from this framework and graph are as follows:

- The driving power-dependence diagram indicates that independent variables of supply chain performance measures in Innovation and Learning Perspective such as *Personnel with related certificates, Training on SCM, Trust with customer, Trust with supplier, % of shared data sets and EDI transactions* are at the bottom of the ISM hierarchy having greater driving power. Thus the management needs to address these enabler variables more carefully in the supply chains. It can be seen that these variables help to achieve the desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that management should devise strategies to enhance the deployment of independent variables so that the productivity and performance are improved.

- *% of sales from new product, New product time-to-market, R&D Investment, Product finalization point, Product category commitment ratio and Performance trajectories of competing technologies* are weak drivers but strongly dependent on other variables. They are seen at the top of the ISM hierarchy. These variables represent the desired objectives of the SCPM system in innovation and learning perspective.

- No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Thus, it can be inferred that among all the 15 variables chosen in this perspective, no variable is unstable.

- No variable is seen as an autonomous variable that has a weak driving power as well as weak dependence. Thus there is no such variable which is isolated from the system.

- The driving power-dependence graph indicates that *VMI & CRP ratio, Supplier development and evaluation system, % of customer sharing forecast and % of supplier sharing forecast* are the regulating variables for the enhancement of productivity and performance of supply chain. These enabler variables appear as moderate driver as well as moderate dependent. They may be helpful for achieving strategic objectives, although their influence on the system is not decisive.

5.5 MICMAC Analysis for The Level Three Framework for Process Perspective, $P_2^3(m_i)$

From the final reachability matrix in the Table 4.18, the driving power and dependence of each measure is plotted on the Driving power x Dependence graph as shown below.

No.		Measures
1	:	Forecast accuracy
2	:	Supply chain cycle efficiency
3	:	Volume flexibility
4	:	Delivery flexibility
5	:	Mix flexibility
6	:	% of supply chain target cost achieved
7	:	Inventory carrying cost
8	:	Supplier delivery performance
9	:	Quality of purchased goods
10	:	Raw material stockout
11	:	Manufacturing productivity
12	:	Work-in-process inventory
13	:	Adherence-to-schedule
14	:	Finished goods inventory
15	:	On time delivery
16	:	Shipping errors
17	:	Truck cube utilization
18	:	Logistics cost

DRIVING POWER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
18		Independent (Driver) Variables									Linkage Variables							
17	1																	
16		8																
15																		
14			7															
13				10														
12						12	11											
11	9		16															
10									13									
9					Regulating Variables					14								
8											15							
7																		
6											17							
5													18					
4																		
3														3				
2												5		4	6			
1		Autonomous Variables									Dependent Variables							2

DEPENDENCE

Figure 5.4: Driving Power x Dependence Graph for Measures in $P_2^3(m_i)$

The driving power of a particular dimension is the total number of dimensions (including itself) which it may help achieve. The dependence is the total number of dimensions which may help achieving it.

Managerial Implications:

Analyzing this graph and the framework $P_2^3(m_i)$ draws very crucial conclusions for the practicing managers about the characteristics of variables. The driving power-dependence graph (Figure 5.4) gives some valuable insights about the relative importance and interdependencies among the measures of Process Perspective of the BSCS. The *managerial implications* emerging from this framework and graph are as follows:

- The driving power-dependence diagram indicates that independent variables of supply chain performance measures in process perspective such as *Forecast accuracy, Inventory carrying cost, Supplier delivery performance, Quality of purchased goods, Raw material stockout, Manufacturing productivity, Work-in-process inventory and Shipping errors* are at the bottom of the ISM hierarchy having greater driving power. Thus the management needs to address these enabler variables more carefully in the supply chains. It can be seen that these variables help to achieve the desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that management should devise strategies to enhance the deployment of these independent variables so that the productivity and performance are improved.

- *Supply chain cycle efficiency, Volume flexibility, Delivery flexibility, Mix flexibility, % of supply chain target cost achieved, Truck cube utilization and Logistics cost* are weak drivers but strongly dependent on other variables. They are seen at the top of the ISM hierarchy. These variables represent the desired objectives of the SCPM system in process perspective.

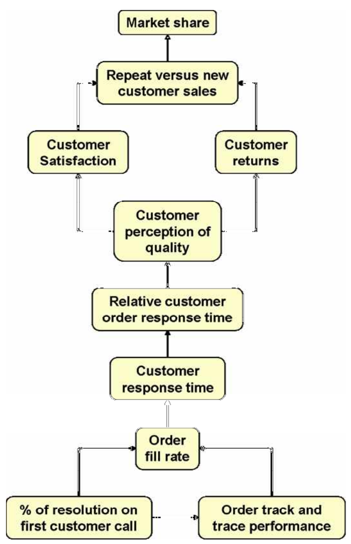
- No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Thus, it can be inferred that among all the 18 variables chosen in this perspective, no variable is unstable.

- No variable is seen as a autonomous variable that has a weak driving power as well as weak dependence. Thus there is no such variable which is isolated from the system.

- The driving power-dependence graph indicates that *Adherence-to-schedule, Finished goods inventory* and *On time delivery* are the regulating variables for the enhancement of productivity and performance of supply chain in process perspective. These enabler variables appear as moderate driver as well as moderate dependent. They may be helpful for achieving strategic objectives, although their influence on the system is not decisive.

5.6 MICMAC Analysis for The Level Three Framework for Customer Perspective, $P_3^3(m_i)$

From the final reachability matrix in the Table 4.25, the driving power and dependence of each dimension is plotted on the Driving power x Dependence graph as shown below.



No.		Dimension
1	:	Customer satisfaction
2	:	Repeat versus new customer sales
3	:	Customer perception of quality
4	:	Customer returns
5	:	% of resolution on first customer call
6	:	Order fill rate
7	:	Order track and trace performance
8	:	Relative customer order response time
9	:	Customer response time
10	:	Market share

DRAWING POWER										
10		Independent (Driver) Variables						Linkage Variables		
9	5, 7									
8			6							
7				9						
6					8					
5			Regulating Variables				3	1		
4								4		
3										
2									2	
1			Autonomous Variables			Dependent Variables				10
	1	2	3	4	5	6	7	8	9	10
	DEPENDENCE									

Figure 5.5: Driving Power x Dependence Graph for Measures in $P_3^3(m_i)$

The driving power of a particular dimension is the total number of dimensions (including itself) which it may help achieve. The dependence is the total number of dimensions which may help achieving it.

Managerial Implications:

Analyzing this graph and the framework $P_3^3(m_i)$ draws very crucial conclusions for the practicing managers about the characteristics of variables. The driving power-dependence graph (Figure 5.5) gives some valuable insights about the relative importance and interdependencies among the measures of Customer Perspective of the BSCS. The *managerial implications* emerging from this framework and graph are as follows:

- The driving power-dependence diagram indicates that independent variables of supply chain performance measures in customer perspective such as *% of resolution on first customer call, Order fill rate, Order track and trace performance and Customer response time* are at the bottom of the ISM hierarchy having greater driving power. Thus the management needs to address these enabler variables more carefully in the supply chains. It can be seen that these variables help to achieve the desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that management should devise strategies to enhance the deployment of these independent variables so that the productivity and performance are improved.

- *Customer satisfaction, Repeat versus new customer sales, Customer perception of quality, Customer returns and Market share* are weak drivers but strongly dependent on other variables. They are seen at the top of the ISM hierarchy. These variables represent the desired objectives of the SCPM system in process perspective.

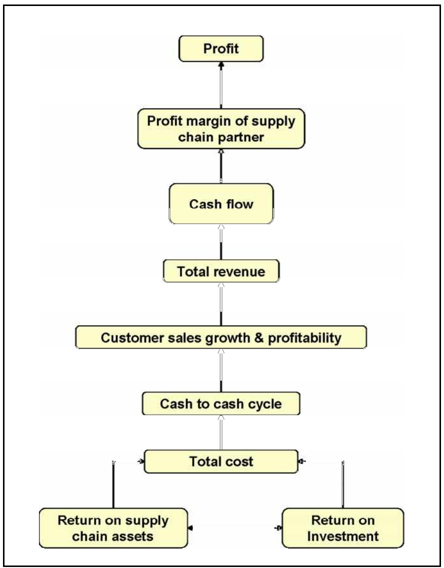
- No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Thus, it can be inferred that among all the 10 variables chosen in this perspective, no variable is unstable.

- No variable is seen as a autonomous variable that has a weak driving power as well as weak dependence. Thus there is no such variable which is isolated from the system.

- The driving power-dependence graph indicates that *Relative customer order response time* is the only regulating variable for the enhancement of productivity and performance of supply chain in customer perspective. This enabler variable appears as moderate driver as well as moderate dependent. It may be helpful for achieving strategic objectives, although its influence on the system is not decisive.

5.7 MICMAC Analysis for The Level Three Framework for Financial Perspective, $P_4^3(m_i)$

From the final reachability matrix in the Table 4.32, the driving power and dependence of each measure is plotted on the Driving power x Dependence graph as shown below.



No.		Measures
1	:	Total revenue
2	:	Customer sales growth & profitability
3	:	Total cost
4	:	Profit
5	:	Profit margin of supply chain partner
6	:	Cash flow
7	:	Cash to cash cycle
8	:	Return on Investment
9	:	Return on supply chain assets

DRIVING POWER									
9		8, 9					Linkage Variables		
8	Independent (Driver) Variables								
7			3						
6			7						
5					2				
4			Regulating Variables			1			
3							6		
2								5	
1			Autonomous Variables			Dependent Variables			4
	1	2	3	4	5	6	7	8	9
					DEPENDENCE				

Figure 5.6: Driving Power x Dependence Graph for Measures in $P_4^3(m_i)$

The driving power of a particular dimension is the total number of dimensions (including itself) which it may help achieve. The dependence is the total number of dimensions which may help achieving it.

Managerial Implications:

Analyzing this graph and the framework $P_4^3(m_i)$ draws very crucial conclusions for the practicing managers about the characteristics of variables. The driving power-dependence graph (Figure 5.6) gives some valuable insights about the relative importance and interdependencies among the measures of Financial Perspective of the BSCS. The managerial implications emerging from this framework and graph are as follows:

- The driving power-dependence diagram indicates that independent variables of supply chain performance measures in financial perspective such as *Total cost, Cash to cash cycle, Return on Investment and Return on supply chain assets* are at the bottom of the ISM hierarchy having greater driving power. Thus the management needs to address these enabler variables more carefully in the supply chains. It can be seen that these variables help to achieve the desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that management should devise strategies to enhance the deployment of these independent variables so that the productivity and performance are improved.

- *Profit, Profit margin of supply chain partner, Total revenue and Cash flow* are weak drivers but strongly dependent on other variables. They are seen at the top of the ISM hierarchy. These variables represent the desired objectives of the SCPM system in financial perspective.

- No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Thus, it can be inferred that among all the 9 variables chosen in this perspective, no variable is unstable.

- No variable is seen as a autonomous variable that has a weak driving power as well as weak dependence. Thus there is no such variable which is isolated from the system.

- The driving power-dependence graph indicates that Customer sales growth & profitability is the only regulating variable for the enhancement of productivity and performance of supply chain in financial perspective. This enabler variable appears as moderate driver as well as moderate dependent. It may be helpful for achieving strategic objectives, although its influence on the system is not decisive.

5.8 MICMAC Analysis for The Level Three Framework (Combined) for $P_c^3(m_i)$

From the final reachability matrix in the Table 4.39, the driving power and dependence of each measure is plotted on the Driving power x Dependence graph as shown below. The driving power of a particular measure is the total number of dimensions (including itself) which it may help achieve. The dependence is the total number of measures which may help achieving it.

Managerial Implications:

Analyzing this graph and the framework $P_c^3(m_i)$ draws very crucial conclusion for the practicing managers about the characteristics of variables. The driving power-dependence graph (Figure 5.7) gives some valuable insights about the relative importance and interdependencies among the measures of BSCS for performance measurement. The managerial implications emerging from this framework and graph are as follows:

- The driving power-dependence diagram indicates that independent variables of supply chain performance measures, such as *Personnel with related certificates, Training on SCM, R&D Investment, % of sales from new product, VMI & CRP ratio, Trust with customer, Trust with supplier, Supplier development and evaluation system, % of shared data sets, EDI transactions, % of customer sharing forecast, % of supplier sharing forecast , Forecast accuracy, Inventory carrying cost, Supplier delivery performance, Quality of purchased goods, Raw material stockout, Manufacturing productivity, Work-in-process inventory, Adherence-to-schedule and Shipping errors* are at the bottom of the ISM hierarchy having greater driving power. Thus the management needs to address these enabler variables more carefully in the supply chains. It can be seen that these variables help to achieve the desired result variables, which appear at the top of the ISM hierarchy. Therefore, it can be inferred that management should devise strategies to enhance the deployment of independent variables so that the productivity and performance are improved.

- *Product finalization point, New product time-to-market, Performance trajectories of competing technologies, Supply chain cycle efficiency, % of supply chain target cost achieved, Customer satisfaction , Repeat versus new customer sales, Customer perception of quality, Customer returns, Relative customer order response time, Market share, Total revenue, Customer sales growth & profitability, Total cost, Profit, Profit margin of supply chain partner, Cash flow, Cash to cash cycle, Return on Investment and Return on supply chain assets* are weak drivers but strongly dependent on other variables. They are seen at the top of the ISM hierarchy. These variables represent the desired objectives of the SCPM system.

- No variable is seen as a linkage variable that has a strong driving power as well as strong dependence. Thus, it can be inferred that among all the 53 variables chosen in this model, no variable is unstable.

- No variable is seen as a autonomous variable that has a weak driving power as well as weak dependence. Thus there is no such variable which is isolated from the system.

- The driving power-dependence graph indicates that *Performance trajectories of competing technologies, Volume flexibility, Delivery flexibility, Mix flexibility, Finished goods inventory, On time delivery, Truck cube utilization, Logistics cost, % of resolution on first customer call, Order fill rate, Order track and trace performance and Customer response time* are the regulating variables for the enhancement of productivity and performance of supply chain. These enabler variables appear as moderate driver as well as moderate dependent. They may be helpful for achieving strategic objectives, although their influence on the system is not decisive.

In this cumulative ISM model of all measures, the apparent anomaly is that many variables which were dependent (or independent) variables in previous models are emerging out as independent (or dependent) in this mode. But the matter of fact is that their pervious model status is only in that particular perspective. This anomaly will disappear if the hierarchy among perspective (P^1) is taken into account. Thus this cumulative model supports the fact that supply chain performance measures follow the hierarchy of perspectives. It can be observed that most of the Innovation and learning perspective measures are at the bottom of the cumulative model. Subsequently there are Process measures and then Customer measures. At the top there are financial measures predominantly. That is the reason why most of the Innovation and learning measures are in the category of independent variables and financial measures are in the category of result variables. If managers want further intervention criterion within each perspective, they may use the model of the respective perspective, which in turn having its own independent and result variables.

5.9 Comparative Analysis with SCOR and ROF Models

The newly developed three tier Integrated BSCS framework is compared with two other famous models in the field of supply chain performance measurement, namely the SCOR model by Supply Chain Council and the R-O-F model by Beamon. These models have been discussed briefly in Chapter-3. This section presents a discussion on the measures in these two models and their possible synthesis with the measures of newly developed Integrated BSCS framework (Figure 5.8). A three axis view for classifying measures based on these three frameworks (SCOR, ROF and Integrated BSCS) is presented for further research.

Figure 5.8 represents this comparative analysis with newly developed framework. The transformation dimensions as suggested by Beamon are in three categories namely, Resource, Output and Flexibility. He has identified supply chain performance measures in these three dimensions for managerial interventions. In SCOR model the orientation of process dimension can be seen from three perspectives namely, Customer facing, Internal Facing and Shareholder facing. These orientations are important from the point of view of targeting the right problem area. If we compare these two models and their orientation of measures with the four perspectives namely, Innovation & Learning, Process, Customer and Financial of the newly developed Integrated Balanced Supply Chain Scorecard Framework, a holistic view can be made about each measure affecting performance of supply chain.

The comparison identifies that each measure of the new framework can be associated with the categories of these two models. The newly developed framework has measures of Financial perspectives which are at the top of ISM Model for the Level Three Framework, $P_c^3(m_i)$. These measures are closely associated with the Output dimension of ROF model and the Shareholder facing dimension of SCOR model. The upper middle part of this ISM model is more concentrated on Customer perspective and measures are mainly associated with the Flexibility dimension of ROF model and the Customer facing dimension of SCOR model. The lower middle part of this ISM model is having Process perspective which in turn is aligned to Resource & Flexibility dimensions of ROF model and the Internal facing dimension of SCOR model. The bottom part measures of the ISM model are mainly from Innovation and Learning Perspective and these measures are not exclusively mentioned in the other two models, but can be approximated to Resource dimensions of ROF model and the Internal facing dimension of SCOR model.

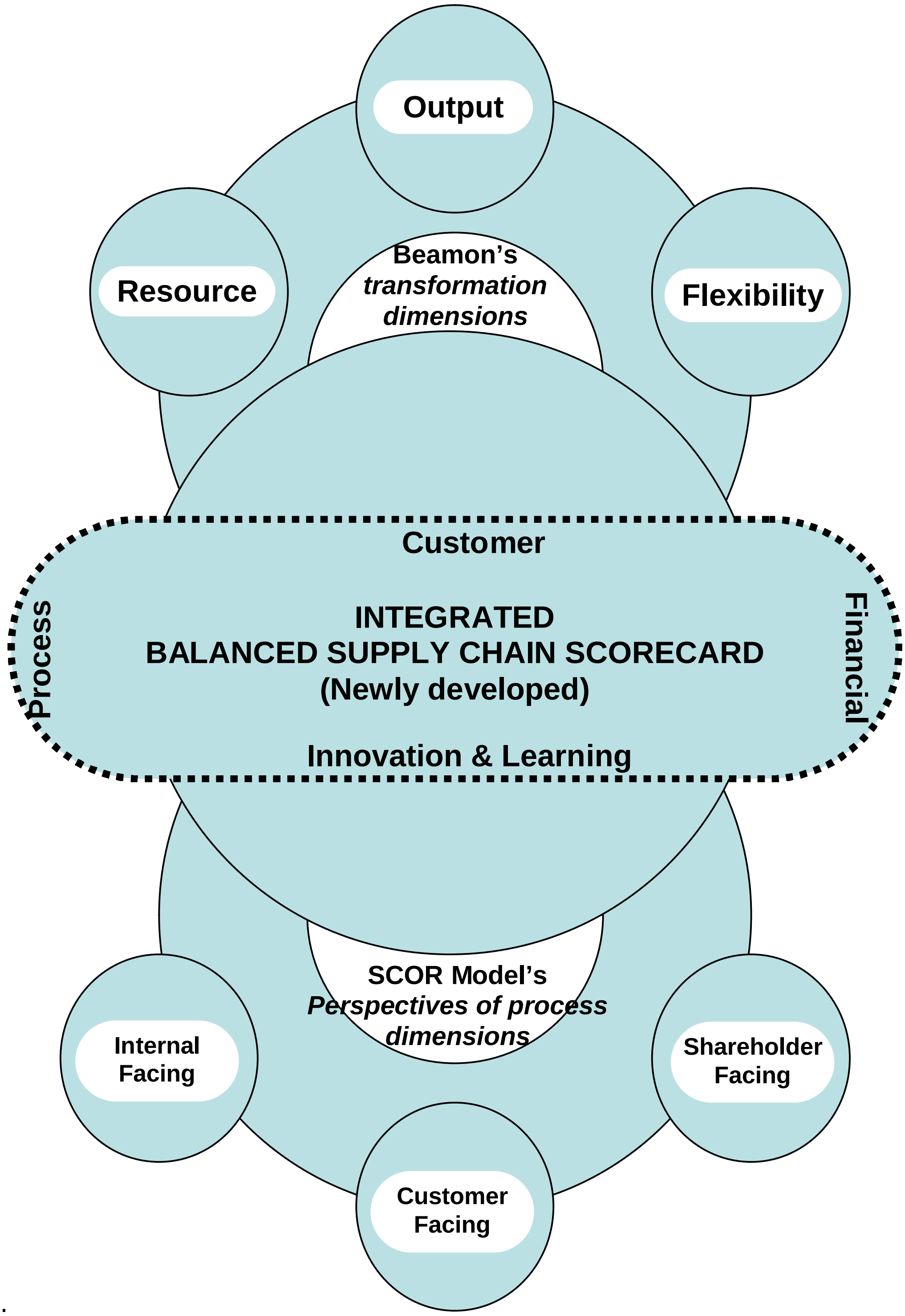


Figure 5.8: Comparative Analysis with SCOR and ROF Models

This comparison is of utmost importance to the practicing managers, because it defines the measures of supply chain performance from different angles. Measures are looked it in their totality and relevance to why they are measured and for what? Thus this developed framework in synchronization to these two models can provide a better insight to supply chain performance measurement. This synthesis will make a universe of supply chain performance measures in three axis system, where each axis is represented by dimension group of each one of these three models (Figure 5.9)

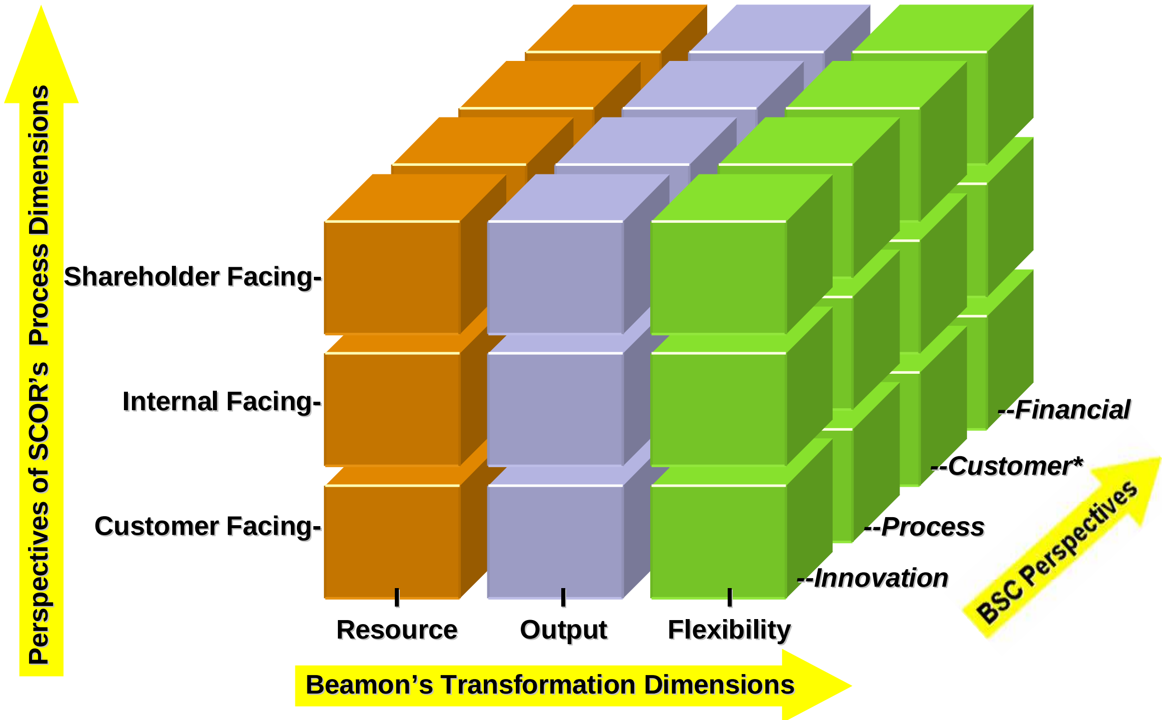


Figure 5.9: Three Axis Universe of Performance Measures

As customer perspective of BSC is same as that of the SCOR model's Customer facing perspective, it is redundant, and hence can be removed. Further, if the *management level dimensions* (Gunasekaran et al., 2001) namely, *strategic, tactical and operational* are also integrated to this modified model, then a comprehensive performance measurement system can be envisioned, which is encompassing every possible managerial orientation required for better decision making (Figure 5.10)

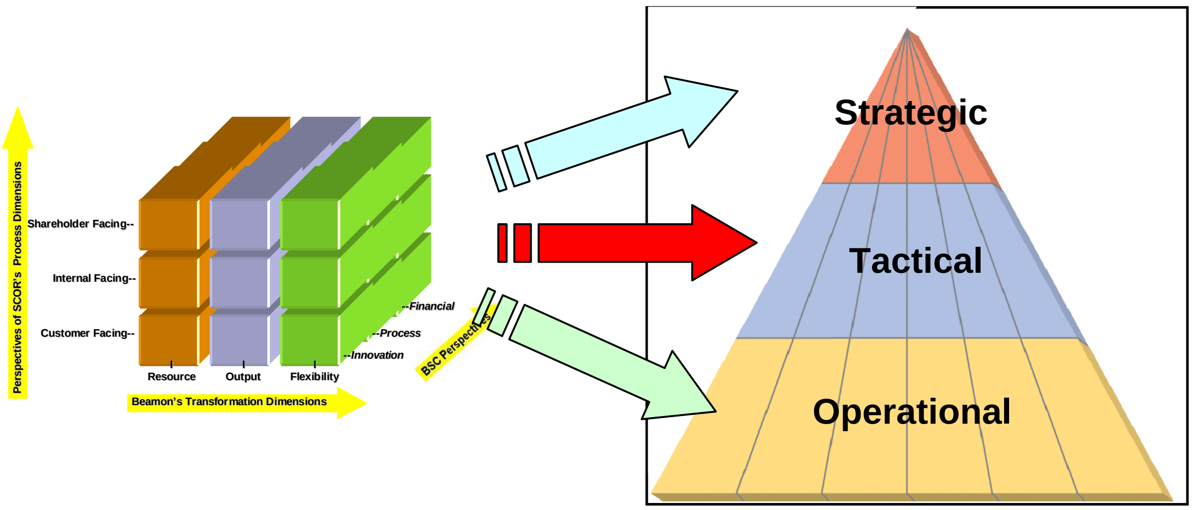


Figure 5.10: Three Axis Universe *(modified)* for each Management Level

Thus in all these three sections discussed before, the newly developed framework of Integrated balanced Supply Chain Scorecard gets sufficient support to be used as an effective tool to find contextual relationships among supply chain performance measures. The hierarchy and the variable classification further enhance the judicious intervention required for successful functioning of supply chain. The overall inter-firm vision of this framework leads to fill the research gap initially identified, so that end-to-end optimization of supply chain performance is possible.

Chapter – 6

Conclusions and Recommendations

The proposed framework for Supply Chain Performance Measurement was developed on the foundations of Balanced Supply Chain Scorecard approach, because of its being holistic in contrast to other frameworks. The Integrated three tier framework was conceptualized on the very fact that the Level One Framework between Perspectives actually exists in the form of strategy maps. An attempt was made to find hierarchical contextual relationships between measures in each perspective which led to development of four such models, one for each perspective. Two combined models were also developed for cumulative measures and for cumulative dimensions taken from all perspectives. The combined model developed, by taking all measures cumulatively projects a complete picture of leading and lagging performance measures.

After proposing this Integrated BSCS, the contextual relationships between measures were to be established for its development. The meta-research methodology was selected for this purpose. Meta-research methodology scans the researches previously conducted, in order to draw conclusion. In other words this is the research about the research. Cases, Surveys, Articles and News Clippings were scanned to arrive at these contextual relationships for each of the proposed model. The ISM methodology was selected to bring out some meaningful structure for the proposed framework. The Structured-Self Interaction Matrix was formulated for all the six models in this effort of finding influence-dependency configuration among measures. Levels were identified after partitioning reachability matrix. The ISM based model was generated with all influence-dependency links shown in these models.

6.1 Specific Contributions

The models developed in the proposed framework, were validated by expert opinion survey. Further MICMAC analysis was done to classify every measure in five variable categories. For this purpose driving power x dependency graph was plotted. This analysis provides a very crucial insight to practicing managers to identify independent variables, which are to be focused with utmost care and urgency in order to influence other variables in dependent variables category. The ***Managerial Implications*** were summarized for each of the developed model. The categorization of performance measures is of utmost importance to managers, as they will be able to comprehend the influence power of measures, for the perspective they are interested in. The decisions are focused, relationships between measures are more visible and efforts are pooled better to achieve strategic objectives.

Developed framework was integrated with two other supply chain performance measurement models, namely SCOR model and Beamon's ROF model to formulate a three axis universe of supply chain performance measures. This universe attempts to look every measure in its totality, so that relevant measures can be identified.

One of the unique contributions of this research is that an effort is made to apply structural modeling in supply chain performance measurement field with Balanced Scorecard Perspectives as focal points. The influence and dependency powers calculated in individual and in combined frameworks are other major findings to conclude that "*Training on SCM*" is one of the most independent variable in whole framework and managers must do consider its importance. The flow can also be identified as financial or product for each framework. The decision hierarchy namely, strategic, tactical and operational is also possible in each framework. These attempts may be targeted in future research.

Development of linkages among various supply chain performance measures through a single systemic framework and utility of the proposed ISM methodology in imposing order and direction on the complexity of relationships among variables of a system assumes tremendous value to the decision makers. The decision making in supply chain performance measurement context is strengthened and supported by this framework due to integrative representation of performance issues.

6.2 Limitations of the Research

This research has a few limitations. As mentioned by one of the experts in his validation comment, all measures are not necessarily involved in every supply chain / industry. Thus few contextual relationships as depicted by the framework, do not at all exist. The framework is generic in nature but should be customizable. In this regard industry-specific, product-specific or even policy-specific modifications must be incorporated. The empirical validation may identify, locate and fill this gap. Statistical validation is missing in this research which may change category of few variables in MICMAC analysis.

The generic characteristic of the framework may also be inappropriate in some situations for the practicing managers. Based on the growth stage in which industry / company presently is, their perspective priority may be different than that suggested in the framework. For a mature company (that want to be more cost-effective) financial perspective or process perspective may have priority as against the customer perspective. This framework has not incorporated this industry / company growth stage factor in its formulation, but as it may play a significant role in deciding the importance, that managers should give to a particular perspective of BSC. Further research should suggest a scheme to target most relevant perspective according to the growth stage.

In the canonical form of final reachability matrix developed in each ISM based model, there are certain entries which reflect inconsistency in the sense that they draw links in which higher level element is influencing the low level element. These inconsistencies are not shown in the developed diagrams, as these diagrams mainly on determine levels. These inconsistencies in each developed model are shown in relevant section of each developed model. These inconsistencies are arising mainly due to the limitations of meta-research methodology. The further research may focus on resolving these inconsistencies by empirical investigations.

Few contextual relationships are dynamic in nature and are dependent on the technological and environmental factors. This may alter the dependence / influence power of variables. Thus this framework must be modified in context of recent environment.

No ranking is done in this analysis for any measure, which is not the case. Some measures are relatively more critical in comparison to other measures, but this ISM technique treats them at par. This limitation of ISM itself may have its impact on the framework.

Validation of the framework by expert opinion survey has its own inbuilt limitations in terms of responses received as they are biased. A broad group of experts must be opinioned for getting a generic consensus in performance measurement framework for supply chains across various industries.

6.3 Recommendations for Future Research

In this research though a relationship model among the supply chain performance measures has been developed, it is not statistically validated. Structural Equation Modeling (SEM), also referred to as the linear structural relationship approach, has the capability of testing the validity of such hypothetical models. Thus this approach can be applied for future research to test the validity of this model. Though SEM is having this capability, it cannot develop initial model for testing, which ISM is capable of. Thus these two modeling techniques in tandem with each other may reinforce and justify the frameworks developed. MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations) method may be another available option to rank measures according to their importance.

As also mentioned before, industry-specific, product-specific or even policy-specific modifications must be incorporated in the framework. The validation comments by expert opinion survey also reflect the need of these modifications. Validation by a pool of experts, from various industries is needed to get a consensus for this generic framework of supply chain performance measurement. This consensus may also resolve opinion differences apparently reflected in comments received from experts.

Suggesting a scheme to target most relevant perspective based on industry growth stage, *Resolving inconsistencies in contextual relationships of few variables by empirical investigations*, *Ranking variables according to their criticality in improving supply chain performance* and *Making framework scalable to incorporate recent issues like environmental concerns and technological breakthroughs* are some other recommendation for further research. The incorporation of these recommendations may overcome the above stated limitations of this research.

Thus this research derives its value from its identification of possible supply chain performance measures, their classification to dimensions and perspectives and then by relative leveling of these measures in individual as well as in combined framework. Managers may use this framework in individual perspective and for overall vision as well. These managerial implications may act as an important and effective support system for managerial decisions towards improvement in supply chain performance.

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Appendix – A

SCPM Research Focus Today

Summary of Recent Contributions by few selected authors

A. Gunasekaran, C. Patel, E. Tirtirpoglu. "Performance measures and metrics in a supply chain environment" University of Massachusetts, Massachusetts, USA. Published in "International journal of Operations & Production management" 2002.

Main Focus: Research on measurement applicable in all supply chains, according to authors. Doesn't seem true within the service sectors

Why measure?: Performance measurements in Supply Chain management are needed to achieve an integrated supply chain. Lack of a balanced approach and lack of a clear distinction between metrics (Von Clausdewitz 3 levels). This paper is theoretical approach, based on literature reviews.

Research strategy: Adopts the definition of a supply chain from J. Steven (flow of products forward, flow of information backward). But focus is on measurements on strategic, tactic, and operational levels. No suggestions, just a presentation on the many metrics applied to day.

Results: Conclusion is that there is no performance measure for the complete supply chain. The paper has just presented the best universal performance measurements. The paper does not establish one uniform approach, and is very fragmented.

Future perspectives: The future holds out for a lean international supply chain. No future research is suggested.

Farri, M.T. & Hutchison, P.D. "Cash to cash: the new supply chain management metric". University of North Texas. Published in "International Journal of Physical distribution & logistics management." 2002

Main Focus: Cash to cash as a new SCM metric applicable in all supply chains, according to the authors.

Why measure?: Purpose of SCM is to achieve lowest cost through synergistic interaction. This means that the speed of the chain is crucial. This speed is measurable by "Cash to cash" time and this should therefore be used as a method

Research strategy: Discuss the definition of what "cash 2 cash" is. Empirical examples by Dell, who have very good "Cash to cash" flow. The use of "cash to cash" as a metric was suggest by a second author Stewart, G.

Results: The cash to cash method is measuring the speed of the supply chain. It is usable through out all supply chains, but it is only measuring out comes. Inputs are still a black box

Future perspectives: C2C is still an inaccurate metric. A more precise method of calculating C2C should be developed. Influence on different levels should as well be researched

Van Hoek, Remko I. "The contribution of performance measurement to the expansion of third party logistics alliances in the supply chain". Cranfield school of management, Cranfield UK. Published in "International journal of Operations & Production management" 2001

Main Focus: Logistics, specially with a focus on Third Party Logistics

Why measure?: Within 3PL, horizontal alliances are required in order to offer the needed services. Recent used measures are insufficient. Measures are needed in order to make this alliances work. Purpose of this paper is to uncover the need for these measures, and in accordance with 3 hypotheses categorize with type measures are needed.

Research strategy: This paper is based on an empirical research based on a questionnaire on a population of 270 respondents (within logistics), with 46 answers (29 %). 3 case studies on 3 logistical providers. It is suggested that integrated logistics, production and customization measures should be used

Results: Focus is horizontal, on the logistical service providers on how they should integrate services by using measurements. Therefore the methods suggested are very specific and narrow.

Future perspectives: No future research is suggested. The tools just need to be applied.

Brewer C.B. & Speh T.W., "Using the Balanced Scorecard to measure supply Chain performance", department of Accountancy & Distribution and Warehousing, Miami University, USA. Published in "Journal of Business Logistics" 2000.

Main Focus: Linkage of Balanced Scorecard and Supply Chain measurement
Why measure?: Old performance measurements do not affect or improve supply chain performance. Their approach emphasizes the balanced measurement to enable the company to succeed in the short and the long term.
Research strategy: Theoretical approach for a conceptual framework.
Results: The authors stress that Balanced Scorecard is a universal tool for each supply chain and -sector. The metrics have to be adjusted to the specific need of the individual supply chains
Future perspectives: New groups of metrics are needed that serve particular supply chain strategies besides the Balanced Scorecard framework.

Stefan Holmberg, "A systems perspective on supply chain measurements", department of Logistics, Lund University, Sweden. Published in "International journal of physical distribution", 2000

Main Focus: A system view. Ikea Sales, wholesaler, development, purchasing organization, 2 key suppliers
Why measure?: There is a disproportion between strategy and the reasonablly used metrics. This causes problems in the supply chain. Author wants to create a tool to improve the performance between units. This destroys the cooperation, and the relationships.
Research strategy: Approach is theoretically, but also based on both quantitative and qualitative research. Interview and questionnaires to actors involved. A system perspective should be applied in the chain, and proper metrics should on this background be chosen.
Results: The system method is useable for all supply chains, but the metrics is unique to each vertical supply chain. This would help the management of the chain.
Future perspectives: More research is needed to support the development of supply chain relationships, and on how measurement models should be used.

Benita M. Beamon, "Measuring Supply Chain Performance". Department of Industrial Engineering, University of Washington, USA. Published in "International Journal of operations and Production Management" 1999.

Main Focus: "Overview and evaluation of the performance measures used in supply chain models and framework for the selection of performance measurement systems for Manufacturing supply chains"
Why measure?: The complexity of the Supply Chain makes it critical to find and use the right performance measures, this research proposes a framework for the right selection of measures
Research strategy: Theoretical approach discussing several performance measures and the combination of those
Results: Result of the this research should deliver a more universal framework for the selection of Supply Chain performance measures
Future perspectives: No research outlook

Peter Gilmor, "A strategic audit framework to improve supply chain performance". Department of Management, Macquire University, Sydney, Australia. Published in "Journal of Business & Industrial Marketing" 1999.

Main Focus: Need for a new set of more strategic measures, compared to formerly more logistics measures in supply chain management
Why measure?: The questionnaire should measure core capabilities within an integrated supply chain and thereby qualify the proposed supply chain framework in the article
Research strategy: Questionnaire of 6 consumer product and 3 automotive companies in Australia to judge the importance of the functions of the proposed SC framework
Results: Framework qualified to evaluate organization’s supply chains
Future perspectives: No research outlook

Stank, T. & Crum, M. & Arango, M.; "Benefits of interfirm coordination in food industry supply chains", Departments of Logistics & Supply Chain Management at Michigan State University and Transportation and Logistics at Iowa State University and Senior Forecast Analyst of Tone, USA. Published in "Journal of Business Logistics" 1999.

Main Focus: Investigation of the relationship between interfirm supply chain coordination and performance of key logistical elements
Why measure?: The results of the survey of suppliers of food products should enable the academics and practitioners to better understand the implications of supply chain processes.
Research strategy: Survey and hypothesis tests of survey in upper management levels of 47 suppliers of food products
Results: Results only applicable to relationship between interfirm coordination and several tested performance indicators.
Future perspectives: Future surveys should measure objective process or activity variables

Van Hoek, Remko I. "Measuring the unmeasureable" (Research paper). Erasmus University, Rotterdam, NL. Published in "Supply Chain Management" 1998

Main Focus: Logistics area
Why measure?: Control is in SCM no longer performed by units, but instead performed by all the participants in the chain. Performance measurements are needed to make the chain transparent, to distribute the control. Papers purpose is to outline the relevance of measurements.
Research strategy: This paper is purely theoretically, based on discussion on other articles. Suggested method is a matrix describing integration and cost, reflecting the strategy applied.
Results: No results at this time. But a definition of SCM is needed. By this, measure metrics should be developed. Tools to these measures should finally be developed. A definition describing all SCMs is needed (but not found)

Future perspectives: "The challenge now is to develop findings that can contribute to actual generation of a supply chain measurement system"

Benita M. Beamon and Tonja M. Ware "A process quality model for the analysis, improvement and control of supply chain Systems". Department of Mechanical, Industrial, and Nuclear Engineering, University of Cincinnati, Cincinnati, Ohio, USA. Published in "Logistics Information management" 1988.

Main Focus: Process Quality Management to improve supply chain control

Why measure?: "The objective of this research is to bridge the gap between supply chain systems analysis and quality control by developing a process quality model (PQM) for the assessment, improvement and control of quality in supply chain systems."

Research strategy: Theoretical approach by applying continuous improvement strategies and modules to supply chain activities.

Results: This approach is meant to cover all supply chain activities and should also be applicable to all different supply chains to improve performance and quality of the processes

Future perspectives: No research outlook

Appendix – B

Supply Chain Performance Measures:

Categories, Classification and Dimensions

Table B.1: Process Performance Measures

(Source: Keebler, J.S. et al. (1999), "Keeping Score", Council of Logistics Management)

Time
On-time Delivery/Receipt
Order Cycle Time
Order Cycle Time Variability
Response Time
Forecasting/Planning Cycle Time
Quality
Overall Customer Satisfaction
Processing Accuracy
Perfect Order Fulfillment
• On-time Delivery
• Complete Order
• Accurate Product Selection
• Damage-free
• Accurate Invoice
Forecast Accuracy
Planning Accuracy
• Budgets and Operating Plans
Schedule Adherence
Cost
Finished Goods Inventory Turns
Days Sales Outstanding
Cost to Serve
Cash-to-Cash Cycle Time
Total Delivered Cost
• Cost of Goods
• Transportation Costs
• Inventory Carrying Costs
• Material Handling Costs
All Other Costs
• Information Systems
• Administrative
Cost of Excess Capacity
Cost of Capacity Shortfall
Other/Supporting
Approval Exceptions to Standard
• Minimum Order Quantity
• Change Order Timing
Availability of Information

Table B.2: Supply Chain Operations Reference (SCOR) Model Performance Measure

(Source: PMG Group (2003), "Boost the Bottom Line with Supply Chain Best Practices" - Signals of Performance, Vol. 4 No.1)

On-Time Delivery
To Request
To Commit
Fill Rate
By order
By line item
Perfect Order Fulfillment
By order
By line item
Supply Chain Response Time
Forecast cycle time
Replan cycle time
Intra-manufacturing cycle time
Cumulative source/make cycle time
Order Fulfillment Lead Time
Customer Signature/Authorization to Order Receipt
Order Receipt to Order Entry Complete
Order Entry Complete to Start Manufacture
Start Manufacture to Order Complete Manufacture
Order Complete Manufacture to Customer Receipt
Customer Receipt to Installation Complete
Upside Production Flexibility
Material
Labor
Capacity
Total Supply Chain Management Costs
Order Management Cost
Material Acquisition Cost
Inventory Carrying Cost
Supply Chain Related Finance and Planning Costs
Supply Chain Related Information Technology Costs
Cash-to-Cash Cycle Time
Days of Inventory -- Raw, WIP, Finished Goods
Days Sales Outstanding
Days Payables Outstanding
Forecast Accuracy
Unit Forecast Accuracy
Dollar Forecast Accuracy
Return
Returns Processing Cost as % Product Revenue
Returns Inventory Status
Return Cycle Times
Cycle time to Process Excess Product Returns for Resale, days
Cycle time to Process Obsolete & End of Life Product Returns for Disposal, days
Cycle time to Repair or Refurbish Returns for Use, days
Percent Actual Achievement versus Published Service Agreement Cycle time, %
# of Repairs performed as % Total # Units Shipped Annually
# of Repairs performed Internally as a % Total # Repairs Performed
# of Repairs performed Externally (by third party) as a % of Total # Repairs Performed
Cost of units repaired/refurbished Internally as a % of Total
Cost of units repaired/refurbished Externally as a % of Total
Financial Metrics
Profitability (EBIT) as % of Revenue
Expenses (SG&A) as % of Revenue
COGS as % of Revenue
Sales Growth (year over year change)
COGS Year over Year Change
Net Asset Turns
Value Added Productivity Per Employee

Table B.3: Functional Performance Measures
(Source: Lapide, 2005)

Customer Service Measures
Line Item Fill Rate
Backorders/stockouts
% Resolution on first customer call
Order track and trace performance
Order entry accuracy
Purchasing Related Measures
Supplier delivery performance
Material stockouts
Material acquisition costs
Administration/Financial Measures
Income
Return on capital employed
Return on investment
Invoice errors
Process, Cross-Functional Measures
Percent perfect orders
New product time-to-first make
Schedule changes
Product quality
Adherence-to-schedule
Cost per unit produced
Setup/Changeover costs
Bill-of-materials accuracy
Plant space utilization
Plant utilization
Source-to-make cycle time
Material usage variance
Production cycle time
Master schedule stability
Market share
Time-to-market
Repeat versus new customer sales
Total landed cost
Total supply chain inventory
Channel inventories
Percent of demand/supply on VMI/CRP
Percent of suppliers getting shared forecast
Internet activity to suppliers/customers
Extended Enterprise Measures
Point of consumption product availability
Retail shelf display
EDI transactions
Percent of customers sharing forecasts
Supplier inventories
Percent automated tendering
Finished goods inventory turns
On-time delivery
Damaged shipments
Pick accuracy
Shipment accuracy
Delivery times
End-of-life inventory
Inventory shrinkage
Documentation accuracy
Warehousing costs
Truck cube utilization
Premium freight charges
Logistic Related Measures
Finished goods inventory days of supply
Lines picked/hour
Inventory accuracy
Logistics cost
On-time shipment
Warehouse space utilization
Obsolete inventory
Cost of carrying inventory
Transportation costs
Container utilization
In-transit inventories
Warehouse receipts
APICS trained personnel
Employee turnover
Order Fill Rate
Quantity Fill Rate
Customer satisfaction
Customer returns
Customer disputes
Order entry times
Material inventories
Material/component quality
Unit purchase costs
Expediting activities
Cash flow
Revenues
Cash-to-cash cycle
Revenue per employee
Return on assets
Forecast accuracy
New product time-to-market
Planning process cycle time
Manufacturing Related Measures
WIP inventories
Yields
Setups/Changeovers
Unplanned stockroom issues
Routing accuracy
Line breakdowns
Warranty costs
Percent scrap/rework
Overtime usage
Manufacturing productivity
Marketing Related Measures
Percent of sales from new products
Percent of products representing 80% of sales
Other Measures
Patents awarded
Number of employee suggestions
APICS trained personnel
Employee turnover

Table B.4: Functional Performance Measures at Different Managerial Levels
(Source: The Open Standards Benchmarking Collaborative (OSBC) Database of APQC, 2005)

Procurement Measures
Executive
Days payable
Dependency on top 10 suppliers
Management
% orders/lines received complete
% of direct materials and services value
% of indirect materials and services value
% of total annual value of materials and services purchased that are included in a formal total cost of ownership (TCO) model
% of total annual value of direct materials and services purchased sourced outside of country
% of purchase orders approved electronically
% of supplier orders delivered on time
% of site's total annual purchases is procured via maverick buying
Total cost of the procurement cycle per purchase order
Operational
% of receipts received without item and quantity verification
% orders/lines received damage free
% orders/lines received defect free
Average transaction amount per purchase
Cycle time in hours to place purchase order
Incoming material quality
Number of FTEs for the process appraise and develop suppliers per $1 billion purchases
Number of FTEs for the process develop sourcing strategies per $1 billion purchases
Number of FTEs for the process order materials/services per $1 billion purchases
Number of FTEs for the process select suppliers and develop/maintain contracts per $1 billion purchases
Number of FTEs for the procurement cycle per $1 billion purchases
% of purchase arrangement type by individual purchase orders
% of purchase arrangement type by other
% of purchase arrangement type by procurement cards
% of purchase arrangement type by replenishment/vendor managed inventory
% of staff having formal training in negotiations
% of staff having over three years of purchasing operations experience
% of staff having over three years of strategic sourcing/commodity management experience
% of strategic suppliers
% of annual purchases value from certified vendors
% of annual value of materials and services using non-traditional purchase order placement for submission of purchase order line items to vendors
% of annual value of purchased material that is received in vendor managed inventory programs
% of purchases (on a dollar basis) transacted via an electronic marketplace
Personnel cost of the process appraise and develop suppliers per $1,000 purchases
Personnel cost of the process develop sourcing strategies per $1,000 purchases
Personnel cost of the process order materials/services per $1,000 purchases
Personnel cost of the process select suppliers & develop/maintain contracts per $1,000 purchases
Procure to pay
Supplier cycle time
Systems cost of the process appraise and develop suppliers per $100,000 purchases
Systems cost of the process develop sourcing strategies per $100,000 purchases
Systems cost of the process order materials/services per $100,000 purchases
Systems cost of the process select suppliers & develop/maintain contracts per $100,000 purchases
Systems cost of the procurement cycle as a percentage of total cost of the procurement cycle
Total cost of the process appraise and develop suppliers per $1,000 purchases
Total cost of the process develop sourcing strategies per $1,000 purchases
Total cost of the process order materials/services per $1,000 purchases
Total cost of the process select suppliers & develop/maintain contracts per $1,000 purchases
Total cost of the procurement cycle per $1,000 purchases
Total cost of the procurement cycle per procurement cycle FTE
Total number of active vendors in the master file per $1 million purchases
Customer Order Management Measures
Executive
Key customer profitability
Market share
Total supply chain management cost as % of revenue
Management

% corrective action 15 days
Customer retention rate
Key customer growth
Key customer retention rate
Number of FTEs for the customer order management function per $1billion revenue
Perfect order performance
Total cost of the customer order management function per $1,000 revenue
Total cost of the customer order management function per sales order line item
Operational
Average cycle time in hours from the time a sales order is received until manufacturing / logistics is notified
Customer order management personnel and systems costs as a % of total cost
Number of FTEs for the process define customer management strategy per $1 billion revenue
Number of FTEs for the process enter, process and track orders per $1 billion revenue
Number of FTEs for the process manage returns per $1 billion revenue
Number of FTEs for the process service customers per $1 billion revenue
Number of sales order line items per enter, process and track orders FTE
Number of sales orders per enter, process, and track orders FTE
% of return product disposed of through donation
% of sales order line items delivered on time
% of return product disposed of through land fill
% of return product disposed of through other method
% of return product disposed of through recycling (materials reclaimed, leased)
% of return product disposed of through remanufacturing and resold through secondary channel
% of return product disposed via sales as scrap
% of return product repackaged and resold through secondary channel
% of return product resold as-is through secondary channel
% of customer orders (by revenue) per non-traditional form of receipt
% of sales order line items changed by the customer following initial order entry
Personnel cost of the process define customer management strategy per $1,000 revenue
Personnel cost of the process enter, process and track orders per $1,000 revenue
Personnel cost of the process manage returns per $1,000 revenue
Personnel cost of the process service customers per $1,000 revenue
Systems cost of the process enter, process and track orders per $100,000 revenue
Systems cost of the process manage returns per $100,000 revenue
Systems cost of the process service customers per $100,000 revenue
Total cost of the process define customer management strategy per $1,000 revenue
Total cost of the process enter, process and track orders per $1,000 revenue
Total cost of the process manage returns per $1,000 revenue
Total cost of the process service customers per $1,000 revenue
Total cost of the process customer order management function per sales order
Logistics Measures
Executive
Customer order cycle time in days
Order fill rate
Management
Total finished goods inventory days of supply
Dock-to-stock cycle time, in hours
Expedited cost as a % of total logistics cost
Inventory accuracy
Line fill rate
Number of FTEs in the logistics function per $1 billion revenue
% of orders scheduled to customer request
% of logistics costs associated with the physical transportation, storage, or handling of
returned product
% of orders shipped complete and on time
% of sales orders delivered on time
Pick-to-ship cycle time for customer orders, in hours
Plant finished goods inventory days of supply
Total cost of logistics per $1,000 revenue
Total cost of the process operate outbound transportation per $1,000 revenue
Total cost of the process operate warehousing per $1,000 revenue
Warehouse slot utilization
Operational
Direct labor availability
Field finished goods inventory days of supply
Freight cost of the logistics cycle as a % of total cost of the logistics cycle
Freight cost of the process operate outbound transportation per $1,000 revenue
Number of FTEs in the process define logistics strategy per $1 billion revenue

Number of FTEs in the process operate outbound transportation per $1 billion revenue
Number of FTEs in the process operate warehousing per $1 billion revenue
Number of FTEs in the process plan inbound material flow per $1 billion revenue
Overhead cost of the process define logistics strategy per $1,000 revenue
Overhead cost of the process operate outbound transportation per $1,000 revenue
Overhead cost of the process operate warehousing per $1,000 revenue
Overhead cost of the process plan inbound material flow per $100,000 revenue
% of full-load trailer/container capacity utilized per shipment
% of late/missed sales order line items not fulfilled due to stockouts
Personnel cost of the process define logistics strategy per $1,000 revenue
Personnel cost of the process operate outbound transportation per $1,000 revenue
Personnel cost of the process operate warehousing per $1,000 revenue
Personnel cost of the process plan inbound material flow per $1,000 revenue
Proportion of direct labor used in logistics not used in direct activity
Return processing cycle time in days
Systems cost of the process define logistics strategy per $1,000 revenue
Systems cost of the process operate outbound transportation per $100,000 revenue
Systems cost of the process operate warehousing per $100,000 revenue
Systems cost of the process plan inbound material flow per $100,000 revenue
Total cost of the process define logistics strategy per $1,000 revenue
Total cost of the process operate outbound transportation per $1000 revenue
Total cost of the process operate warehousing per $1,000 revenue
Total cost of the process plan inbound material flow per $1,000 revenue
Unit fill rate
Value of late/missed sales order line items not fulfilled due to stockouts, as a % of revenue
Manufacturing Measures
Executive
Asset turns
Inventory days of supply
Inventory obsolescence as a % of total inventory
Number of returned items as a % of the total number of products sold
% of defective parts per million
Management
Finished product, first pass quality yield
Manufacturing cycle time in hours
Raw material or product days-of-supply
Scrap & rework costs as a % of sales
Standard customer lead time (order entry to shipment) in days
Total value of returned products as a % of annual sales
Value of plant shipments per manufacturing employee
Warranty costs (repair & replacement) as a % of sales
Work-in-process (WIP) days inventory on hand
Operational
Actual production rate as a % of the maximum capable production rate
Cost of in-process product (WIP) damaged from handling/storage as a % of total material cost
Direct labor availability
ECO (Engineering Change Order) cycle time
ECO cost as a % of total new product development cost
Labor turnover rate as a % of work force
Manufacturing controllable cost
Production material handling damage
Production plan adherence/production schedule attainment for a planning period
Proportion of direct labor used in manufacturing not used in direct activity
Raw material shrinkage
Total WIP inventory days of supply
Unplanned machine downtime as a % of scheduled run time
New Product Development Measures
Executive
% of new product/service developments launched on budget
% of new product/service developments launched on time
% of sales due to product/services launched in the past year
Time to market in days for new product/service development projects
Management
Cost of new product/service opportunities per $1,000 revenue
Number of FTEs for new product development per $1 billion revenue
% of sales that is a result of products/services that have been launched in the past year
% of existing product/service improvements launched on budget

% of new product/service developments launched on budget
Total cost of new product development per $1,000 revenue
Cost of product/service extensions per $1,000 revenue
Cost of product/service improvements per $1,000 revenue
Average design cycle time (days) for all types of new products (incl. Improvements and extensions)
Number of FTEs for the process design and develop product/service ideas per $1 billion revenue
Number of FTEs for the process generate new product/service ideas per $1 billion revenue
Number of FTEs for the process support product/service manufacturing/delivery per $1 billion revenue
% of site's product/service development projects launched as commercial products/services annually
% of existing product/service extensions launched on budget
% of existing product/service extensions launched on time
Personnel cost of the process design and develop product/service per $1,000 revenue
Personnel cost of the process generate new product/service ideas per $1,000 revenue
Personnel cost of the process support product/service manufacturing/delivery per $1,000 revenue
Personnel cost of the process test market product/service per $1,000 revenue
Ratio of projects entering the design and develop product/service process to projects completing the process
Time to market in days for existing product/service extension projects
Time to market in days for existing product/service improvement projects
Time to profitability in days for existing product/service extension projects
Time to profitability in days for existing product/service improvement projects
Time to profitability in days for new product/service development projects
Total cost of the process design and develop product/service per $1,000 revenue
Total cost of the process generate new product/service ideas per $1,000 revenue
Total cost of the process support product/service manufacturing/delivery per $1,000 revenue
Total cost of the process test market product/service per $1,000 revenue
Supply Chain Planning Measures
Executive
Annual total inventory turn rate
Cash to cash cycle time
Return on assets
Value add productivity per employee
Management
Money forecast accuracy as a % of money shipped
Demand/supply planning costs
Employee retention
Forecast accuracy one planning period prior to production run
Inventory carrying cost
Number of FTEs for the supply chain planning function per $1billion revenue
Shrinkage
Total annual cost of quality per $1000 revenue
Unit forecast accuracy as a % of units shipped

Table B.5: Definition of Supply Chain Performance Measures

(Source: http://www.isli.bordeaux-bs.edu/isli_score/glossary/index.htm)

# of call backs as % of total inquiries	Number of callbacks divided by total inquiries.
% Defective	The percentage of time a product is considered unacceptable against standard criteria. The # of unacceptable products divided by the total number of units produced during the manufacturing run.
% Invoices processed without issues and/or errors	The number of invoices processed without issues and or errors divided by the total number of invoices processed in the measurement period
% of Data Accuracy	Amount of valid MAKE information divided by original source data.
% of Downtime Due to Non-availability of WIP	The % of time an equipment/operation is idle due to no WIP in queue for that particular equipment/operation.
% of EDI Transactions	Percentage of orders received via electronic data interchange, EDI.
% of Faultless Installations	Number of Faultless Installations divided by Total Number of Units Installed.
% of Faultless Invoices	The number of invoices issued without error. Examples of potential invoice defects are: Change from customer purchase order without proper customer involvement; Wrong Customer Information (e.g., name, address, telephone number); Wrong Product Information (e.g., part number, product description); Wrong Price (e.g., discounts not applied); Wrong Quantity or Wrong Terms or Wrong Date
% of Information Management Assets Used / Production Assets	Information technology capital assets that support production operations / total capital assets devoted to production operations.
% of Invoice Receipts and Payments Generated via EDI	# of EDI generated invoices divided by the total number of invoices.
% of Orders Scheduled to Customer Request	The percentage of orders whose delivery is scheduled to within an agreed to time frame of the customer's requested delivery date.
% of Parts Delivered To Point of Use	The percentage of material receipts that are delivered directly to production or a consolidation point or to point of use on the production floor with no inspection or minor visual/paperwork inspection only.
% of Potential Suppliers Selected which Become Qualified	The number of suppliers who become "qualified" divided by the total number suppliers who were selected for qualification in the measurement period
% of Qualified Suppliers which Meet Defined Requirements	The number of qualified suppliers who meet defined requirements divided by the total number of qualified suppliers used as sources in the measurement period
% of Receipts Received without Item and Quantity Verification	# of receipts with Quantity variance requiring corrective actions (outside industry standard tolerance) divided by total number of receipts.
% of Receipts Received without Quality Verification	# of receipts with Quality variance requiring corrective actions divided by total number of receipts.
% of Single and/or Sole Source Selections	# of Single and/or Sole Source selections divided by the total number of awards
% of Supplier Contracts Negotiated	The number of contracts negotiated meeting all business requirements divided by the total number of contracts processed in the measurement period
% of Time Data Available When Needed	The amount of time that data is accessible by applications during those time periods when it is scheduled to be available. Data availability is often measured as a percentage of an elapsed year.
% Orders/Lines Processed Complete	The number of orders / lines that are processed complete divided by the total orders / lines processed within the measurement period

% Orders/Lines Received Complete	The number of orders / lines that are received complete divided by the total orders / lines received in the measurement period
% Orders/Lines Received Damage Free	The number of orders / lines that are processed damage free divided by the total orders / lines processed in the measurement period
% Orders/Lines Received Defect Free	The number of orders / lines that are received defect free divided by the total orders / lines processed in the measurement period
% Orders/Lines Received On-Time To Demand Requirement	The number of orders / lines that are received on-time to the demand requirements divided by the total orders / lines for the demand requirements in the measurement period
% Orders/Lines Received With Correct Shipping Documents	The number of orders / lines that are received on-time with correct shipping documents divided by the total orders / lines processed in the measurement period
% Product Transferred Complete	The number of orders / lines that are transferred complete divided by the total orders / lines transferred in the measurement period.
% Product Transferred Damage Free	The number of product orders/lines that are transferred damage free divided by the total orders / lines processed in the measurement period
% Product transferred on-time to demand requirement	The number of product orders / lines that are transferred on-time to demand requirements divided by the total orders / lines transferred in the measurement period
% Product transferred without transaction errors	The number of transactions processed without error divided by the total transactions processed in the measurement period
% Schedules changed within Supplier's Lead Time	The number of schedules that are changed within the suppliers lead-time divided by the total number of schedules generated within the measurement period
% Schedules generated within Supplier's Lead Time	The number schedules generated within the suppliers lead-time divided by the total schedules generated in the measurement period
Actual Asset Life Maintenance Cost as % of Replacement Value	The process of identifying, prioritizing, and considering, as a whole with constituent parts, all sources of demand in the delivery of a product or service.
Actual-to-Theoretical Cycle Time	The process of identifying, prioritizing, and considering, as a whole with constituent parts, all sources of demand for a product or service in the supply chain.
Administrative Costs Associated with In-Transit and handling/Movement of In-Process Product	The process of identifying, prioritizing, and considering as a whole with constituent parts, all sources of demand in the creation of a product or service.
Asset Turns	The process of identifying, prioritizing, and considering as a whole with constituent parts, all requirements that must be satisfied by the supply chain execution.
Average days per Engineering Change	Courses of action over specified time periods that represent a projected appropriation of total supply-chain resources to meet total supply-chain demand requirements.
Average days per Schedule Change	The physical movement of materials (e.g., raw materials, fabricated components, manufactured subassemblies, required ingredients or intermediate formulations) from a stocking location (e.g., stockroom, a location on the production floor, a supplier) to a specific point of use location. Issuing material includes the corresponding system transaction. The bill of materials/routing information or recipe/production instructions will determine the materials to be issued to support the manufacturing operation(s).
Average Plant-Wide Salary	A record of specific information for each product, which defines the system parameters with which to effectively plan and execute using ERP (MRP, etc) systems.
Average Release Cycle of Changes	The series of task including placing product onto vehicles, generating the documentation necessary to meet internal, customer, and government needs, and sending the product to the customer.
Build To Ship Cycle Time	The ongoing management of the activities associated with ensuring equipment and facilities are kept in proper order. This process element includes required repairs, alterations, calibration, and other miscellaneous items to maintain production capability of the manufacturing fixed asset base.

Capacity Utilization	A measure of how intensively a resource is being used to produce a good or service. Some factors that should be considered are internal manufacturing capacity, constraining processes, direct labor availability and key components/materials availability.
Cash-to-Cash Cycle Time	Cash-to-cash cycle time = inventory days of supply + days sales outstanding - average payment period for materials (time it takes for a dollar to flow back into a company after its been spent for raw materials). For services, this represents the time from the point where a company pays for the resources consumed in the performance of a service to the time that the company received payment from the customer for those services.
Commodity Management Profile	Number of distinct part numbers (purchased commodities) or service components/ resources sourced within the following areas: 200 miles, own country, own continent, and off - shore.
Complete Manufacture to Order Ready for Shipment Time	Includes pick/pack and prepare for shipment time, in calendar days.
Cost of compliance including administrative costs	Total MAKE cost to comply with regulatory requirements.
Cost of Goods Sold	The cost associated with buying raw materials and producing finished goods. This cost includes direct costs (labor, materials) and indirect costs (overhead).
Cost of In-Process Product (WIP) Damaged from Handling/Storage as a Percentage of Total Material Cost	The costs of in-process product (WIP) damaged from handling/storage divided by the total cost of those materials.
Cost of Managing MAKE Information	The cost of managing, updating, and maintaining the information technology systems that support manufacturing operations.
Cost of Noncompliance	Measure of the MAKE costs for non-conformance with regulatory documentation and process standards set by external entities (e.g. government).
Cost per Invoice	All costs associated with the receipt, review, processing, and payment of a supplier's invoice for product received.
Costs Associated with Managing Production Performance as a % Manufacturing Controllable Cost	Ratio of Cost for Managing Production Performance to Manufacturing Controllable Cost.
Create Customer Order Costs	Includes costs for creating and pricing configurations to order and preparing order documents.
Cross training	The providing of training or experience in several different areas (e.g., training an employee on several machines rather than one). Cross - training provides backup workers in case the primary operator is unavailable.
Cumulative Source/Make Cycle Time	The cumulative external and internal lead-time to build shippable product (starting with no inventory on-hand, no parts on-order, and no prior forecasts existing with suppliers), in calendar days.
Customer Invoicing/ Accounting Costs	Includes costs for invoicing, processing customer payments, and verifying customer satisfaction.
Customer Receipt of Order to Installation Complete	Includes product installation, acceptance and product up and running time, in calendar days.
Customer Signature/Authorization to Order Receipt Time	Time, in calendar days, from when the customer authorizes an order to the time that the order is received.
Days Sales Outstanding	5 point annual average of gross accounts receivable ÷ (total gross annual sales ÷ 365)
Deliver Cycle Time	All time associated with unloading, receiving, inspecting, and placing incoming materials into inventory and processing payment to the supplier including recording exceptions, moving incoming materials to storage location, and inputting data into inventory systems.

Delivery Performance to Customer Commit Date	The percentage of orders that are fulfilled on or before the original scheduled or committed date.
Delivery Performance to Customer Request Date	The percentage of orders that is delivered on the customer's requested date.
Demand/ Supply Planning Costs	The process of specifying, maintaining and dispositioning. Make's capital assets to operate the supply chain production processes. This includes repair, alteration, calibration and other miscellaneous items to maintain production capabilities.
Distribution Costs	Includes costs for warehouse space and management, finished goods receiving and stocking, processing shipments, picking and consolidating, selecting carrier, and staging products/systems.
Documentation	Number of orders without correct documentation supporting the order, including packing slips, bills of lading, invoices, etc.
Downside Delivery Flexibility	Percentage delivery reduction sustainable at 30 days prior to delivery with no inventory or cost penalties.
Downside Installation Flexibility	Percentage installation reduction sustainable at 30 days prior to installing with no inventory or cost penalties.
Downside Order Flexibility	Percentage order reduction sustainable at 30 days prior to shipping with no inventory or cost penalties.
Downside Production Flexibility	The percentage order reduction sustainable at 30 days prior to delivery with no inventory or cost penalties.
Downside Shipment Flexibility	Percentage shipment reduction sustainable at 30 days prior to shipping with no inventory or cost penalties.
Downtime in MAKE Due To Compliance Issues	The measure of process downtime due to noncompliance to external and internal regulatory documentation or process standards (e.g. specifications, SPC, governmental regulations, etc.)
ECO (Engineering Change Order) Cycle Time	The total time required from request for change from customer, engineering, production or quality control to revise a blueprint or design released by engineering, and implements the change within the Make operation.
ECO cost	Costs incurred from revisions to a blueprint or design released by engineering to modify or correct a part. The request for the change can be from a customer or from production quality control or another department.
End-of-Life Inventory	Inventory on hand which will satisfy future demand for products that are no longer in production at your entity.
Equipment Utilization	Number of filled equipment SKU locations divided by the total SKU locations provided by the equipment expressed as a percentage
Equipment/Facility Maintenance Cost as % of Manufacturing Controllable Cost	Cost to repair, alter, calibrate and maintain production equipment divided by total Manufacturing Controllable Cost.
Field Finished Goods Inventory Days of Supply	The inventory which is kept at locations outside the four walls of the manufacturing plant, i.e. distribution center, warehouse.
Fill Rates	The percentage of ship-from-stock orders shipped within 24 hours of order receipt. For services, this metric is the proportion for services that are filled so that the service is completed within 24 hours
Finished Goods Inventory Carrying Costs	Sum of all costs associated with finished goods inventory: opportunity cost, shrinkage, insurance and taxes, total obsolescence, channel obsolescence and field sample obsolescence.
Finished Goods Inventory Days of Supply	Finished goods inventory days of supply are calculated as gross finished goods inventory ÷ (value of transfers/365 days).
Finished Goods Inventory Days of Supply	Plant finished goods inventory days of supply are calculated as gross plant finished goods inventory ÷ (value of transfers/365 days).

Forecast Accuracy	Forecast accuracy is calculated for products and/or families for markets/distribution channels, in unit measurement Forecast Accuracy = Forecast Sum - Sum of Variance Forecast Sum Where: Forecast Sum = The sum of the units forecasted to be shipped in each month based upon the forecast generated at the critical time fence Sum of Variances = The sum of the absolute values, at the forecasted line item level, of the differences between each month's forecast as defined above and actual demand for the same month.
Forecast Cycle	The time between forecast regenerations that reflect true changes in marketplace demand for deliverable end products. Only true "bottoms-up" forecasts are counted: for example, if weekly or monthly updates to the forecast only re-calendar or shift dates for the forecast to avoid changing the annual dollar-based forecast, they should not be considered true forecast regenerations.
Incoming Material Quality	# Of received parts which fail inspection divided by the total # of parts received
Indirect to Direct Labor Headcount Ratio	Ratio of total number of employees required to support production in general without being related to a specific product, indirect labor, to the total number of employees that is specifically applied to the product being manufactured or used in the performance of the service, direct labor.
In-Process Failure Rates	The percentage of time work-in-process is not completed. 1 minus the percentage of completed work-in-process units.
Installation Costs	Includes costs for verifying site preparation, installing, certifying, and authorizing billing.
Intra-Manufacturing Re-Plan Cycle	Time between the acceptance of a regenerated forecast is by the end-product producing location and the reflection of the revised plan in the master production schedule of all the affected plants, excluding external vendors.
Inventory Accuracy	The absolute value of the sum of the variance between physical inventory and perpetual inventory
Inventory Aging	The percentage of total gross inventory (based on value) covered by expected demand within specific time buckets.
Inventory Cycle Counting Accuracy	The absolute value of the sum of the variance between physical inventory and perpetual inventory. Or the number of accurate part cycle counts divided by the total number of cycle counts performed expressed as a percentage.
Inventory Days of Supply	Total gross value of inventory at standard cost before reserves for excess and obsolescence. Only includes inventory on company books, future liabilities should not be included. Five point annual average of the sum of all gross inventories (raw materials & WIP, plant FG, field FG, field samples, other) ÷ (COGS ÷ 365).
Inventory Obsolescence as a % of Total Inventory	The annual obsolete and scrap reserves taken for inventory obsolescence expressed as a percentage of annual average gross inventory value.
Item/Product/Grade Changeover Time	The time required for a specific machine, resource, work center, process, or line to convert from the production of the last good piece of item/product/grade of A to the first good piece of item/product/grade of B.
Machine Wait Time	The percentage of time a machine facility is idle; 1 minus the utilization rate.
MAKE Cycle Time	The sum of the following average times: Order release to start actual build + Total build cycle + End build to leaves plant (i.e., moves to on/off-site distribution or goes to customer). For continuous and mixed processes, manufacturing cycle time is calculated as the average number of units (doses, kilos, pounds, gallons, etc.) in process divided by the average daily output in units.
Management Decision Timeframe Ratio	The ratio of the time needed to make a decision about a particular process divided by the cycle time of that process. (This generates a number that is better if it is lower). For example, if an operation can be performed in 2 hours, and it takes 4 hours to make a decision about that operation, the ratio would be 200%. The Timeframe would be affected by the time it takes to collect data, process information, develop knowledge and evaluate the situation, and implement the decision.
Manufacturing Controllable Cost	All costs under direct control of the MAKE function. These costs are: direct labor and expenses, indirect labor and expenses, asset charges, and excess material & packaging costs. (Raw and packaging materials used to make a finished good are not included.)

Material Requisition Cycle Time	The total amount of time required converting the identification of capacity needs for key material resources to the receipt of those resources.
Mean Time Between Failure	The average time interval between failures for repairable equipment and facilities for a defined unit of measure (e.g. operational hours, cycles, miles).
Mean Time to Repair Asset	The average time to repair equipment and facilities for a defined unit of measure (e.g. operational hours, cycles, miles).
Number of ECOs	Total number of revisions to a blueprint or design released by engineering to modify or correct a part, engineering change orders (ECO). The request for the change can be from a customer or from production quality control or another department.
Number of Supply Sources	Total number of internal and external direct production material suppliers used.
On Time in Full	Number of orders for which not all of the items on order are delivered in the quantities requested.
Order Consolidation Profile	Consolidation is defined as the activities associated with filling a customer order by bringing together in one physical place all of the line items ordered by the customer. Some of these may come directly from the production line and others may be picked from stock. The following profiles have been captured; Shipped direct to customer's dock from point of manufacture (No Consolidation); Shipped direct to the customer with consolidation completed, local to customer by your transport company; Moved to on-site staging location for consolidation and shipment direct to customer; Moved to on-site stockroom for later pick, pack and ship; Shipped to different locations for consolidation or later pick, pack and ship.
Order Entry and Maintenance Costs	Includes costs for maintaining the customer database, credit check, accepting new orders and adding them to the order system as well as later order modifications.
Order Entry Complete to Order Ready for Shipment Time	Including release to manufacturing, order configuration verification, production scheduling, build, pick/pack, and prepare for shipment time, in calendar days.
Order Entry Complete to Start Manufacture Time	Time from completion of order entry to that of the release to manufacturing, in calendar days.
Order Fulfillment Costs	Includes costs for processing the order, allocating inventory, ordering from the internal or external supplier, scheduling the shipment, reporting order status and initiating shipment.
Order Fulfillment Cycle Time	The average actual lead times consistently achieved, from Customer Signature/ Authorization to Order Receipt, Order Receipt to Order Entry Complete, Order Entry Complete to Start-Build, Start Build to Order Ready for Shipment, Order Ready for Shipment to Customer Receipt of Order, and Customer Receipt of Order to Installation Complete.
Order Management Costs	The aggregation of the following cost elements (contained in this glossary):Create Customer Order Costs; Order Entry and Maintenance Costs; Contract/Program and Channel Management Costs; Installation Planning Costs; Order Fulfillment Costs; Distribution Costs; Transportation Costs; Installation Costs; Customer Invoicing/Accounting Costs
Order Management Cycle Time	The total amount of time required converting a customer order into a receipt by the customer.
Order Ready for Shipment to Customer Receipt of Order Time	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.
Order Receipt to Order Entry Complete Time	Time required, in calendar days, for order revalidation, configuration check, credit check, and scheduling of received orders.
Overhead Cost	Costs incurred in the operation of a business that cannot be directly related to the individual products or services produced. These costs, such as light, heat, supervision, and maintenance, are grouped in several pools and distributed to units of product or service by some standard allocation method such as direct labor hours, direct labor dollars, or direct materials dollars.
Package Cycle Time	The total time required to perform a series of activities that containerize completed products for storage or sale to end-users. (Within certain industries, packaging may include cleaning or sterilization.)

Packaging Cost	The cost to package product as a finished good, not including intermediate handling of materials, based on given number of Delivered Finished Goods.
Perfect Order Fulfillment	A "perfect order" is defined as an order that meets all of the following standards: Delivered complete: all items on order are delivered in the quantities requested Delivered on time to customer's request date, using customer's definition of on-time delivery Documentation supporting the order including packing slips, bills of lading, invoices, etc., is complete and accurate Perfect condition: Faultlessly installed (as applicable), correct configuration, customer-ready, no damage
Plant Cost Per Hour	Total planning expenditures divided by the total number of hours spent exercising the plan
Plant-Level Order Management Costs	The aggregation of the following cost elements for which manufacturing is central focal point of orders (contained in this glossary):Create Customer Order Costs; Order Entry and Maintenance Costs; Contract/Program and Channel Management Costs; Installation Planning Costs; Order Fulfillment Costs; Distribution Costs; Transportation Costs; Installation Costs; Customer Invoicing/Accounting Costs
Product Acquisition Costs	Product acquisition costs include costs incurred for the production of product: sum of product management and planning, supplier quality engineering, inbound freight and duties, receiving and product storage, incoming inspection, product process engineering and tooling costs.
Product Losses (Sourced/in-process/finished)	The total cost of lost material from receipt and inspection of raw materials to the shipping of the finished good, per given number of Inventory Turns or Delivered Finished Goods.
Product Management and Planning Costs as a % of Product Acquisition Costs	Product (Commodity) Management and Planning - All costs associated with supplier sourcing, contract negotiation and qualification and the preparation, placement, and tracking of a Purchase Order expressed as a percentage of product acquisition costs. This category includes all costs related to buyer/planners.
Product Process Engineering as a % of Product Acquisition Costs	Product Process Engineering Cost associated with tasks required to document and communicate product specification, as well as reviews to improve the manufacturability of the purchased item expressed as a percentage of product acquisition costs.
Product Structure	Recipes / formulas / BOMs / that define the composition of a product
Product Structure Cycle Time	Total time from demand to release of product structure
Production Material Administrative Cost	Administrative costs associated with the handling / storage / movement of materials
Production Material Cycle Time	Time required moving material to point of use.
Production Material Handling Cost	Cost of handling/movement of materials used to support production.
Production Material Handling Damage	Cost of material damaged from handling / storage / movement as a percentage of total material cost.
Production Material Storage Cost	Cost of storage space used for the production materials.
Production Rules Preparation Cycle Time	Total Time from demand rules for production rules until releases of production details.
Production Plan Adherence	Production Plan Adherence is calculated at the shippable end-product level in units: Production Plan = Sum of Variance - Production Plan Where: Production Plan = The sum of the units planned to be completed (placed into inventory or shipped) in each month based upon the plan generated in the previous month Sum of Variances = The sum of the absolute values, at the end item level, of the differences between each month's production plan as defined above and actual production for the same month.

Published Delivery Cycle Time	The typical standard lead-time (after receipt of order) currently published to customers by the sales organization. For typical orders only, not standing/re-supply orders.
Published Delivery Lead Times	The typical standard lead-time (after receipt of order) currently published to customers by the sales organization. For typical orders only, not standing/re-supply orders.
Purchased Product by Geography	Number of the following distinct part numbers of: Raw materials, Externally manufactured intermediates, Toll manufactured finished products, Packaging product, Labeling product that are sourced within the following areas: 200 miles, Own country, Own continent, Off-shore.
Quarantine Time	Setting aside of items from availability for use or sale until all required quality tests have been performed and conformance certified.
Ratio of Actual To Theoretical Cycle Time	The ratio of the measured time required for completion of a set of tasks divided by the sum of the time required to complete each task based on the rated efficiency of the machinery and labor operations.
Ratio of the Cost of Managing MAKE Information/Manufacturing Controllable Costs	The ratio of these two metrics provides an understanding into the effect of IT on the Make operating cost.
Raw Material & WIP Inventory Days of Supply	Raw material & WIP inventory days of supply are calculated as gross raw material and WIP inventory ÷ (value of transfers/365 days).
Raw Material or Product Days-of-Supply	Raw material or product inventory days of supply are calculated as gross raw material or product inventory ÷ (value of transfers/365 days).
Raw Material Shrinkage	The costs associated with breakage, pilferage, and deterioration of raw material inventories.
Receiving & product storage costs as a % of Product Acquisition Costs	Receiving and Product Storage - All costs associated with taking possession of and storing product. Includes warehouse space and management, product receiving and stocking, processing work orders, pricing, and internal product movement. This does not include incoming inspection.
Receiving and Put Away Cycle Time	The total amount of time required moving materials from an inbound location to an internal storage location.
Receiving costs as a % of Product Acquisition Costs	All costs associated with taking possession of product expressed as a percentage of product acquisition costs. This does not include inspection.
Receiving Cycle Time	Total elapsed time from time product is received to time it is passed to next process
Regulatory Documentation Cycle Time	The time required to complete regulatory documentation during a production run. The product cycle less this metric is the basic production cycle time. Does not include required product data collection for quality or process improvement.
Re-plan Cycle Time	The time between the initial creation of the regenerated forecast and its reflection in the Master Production Schedule of the end-product production facilities.
Responsiveness Lead Time	Minimizing elapsed time, including all delays, to receive a customer order and transform resources into goods and services, through to the point of customer receipt.
Return on Assets	A financial measure of the relative income-producing value of an asset. It is calculated as net income divided by total assets.
Sales Per Employee	Total product revenue divided by total number of full-time equivalent employees
Schedule Achievement	The percentage of time that a plant achieves its production schedule. This calculation is based on the number of scheduled end-items or total volume for a specific period. Note: over-shipments do not make up for under-shipments.
Schedule Interval	This is the measure of the time required to regenerate the schedule to manufacture specific parts, products, or formulations in specified quantities within a specific time frame. The schedule interval must be less than the manufacturing cycle time to be
Scheduled Resource Cost	The measure of the cost of people, information systems, management direction, and any other costs associated with provided schedules for manufacturing.

Scrap expense	Expenses incurred from material falling outside of specifications and possessing characteristics that make rework impractical.
Shrinkage	The costs associated with breakage, pilferage, and deterioration of inventories.
SKU	Stock keeping unit
Source Cycle Time	Cumulative lead-time (total average combined inside-plant planning, supplier lead time [internal or external], receiving, handling, etc. from demand identification at the factory until the products are available in the production facility) required sourcing 95% (chosen to eliminate outlying data) of the dollar value of products from internal and external suppliers.
Source Flexibility	The time required to achieve a sustained increase in volume by 20%.
Source Identification Cycle Time	Total elapsed time from the time the requirement is identified until the source(s) are identified.
Source Qualification Cycle Time	Total elapsed time from time the source is identified until it is qualified and approved.
Source Selection Cycle Time	Total elapsed time from the time the RFQ is created until the contract is awarded and accepted by the supplier.
Sourced/In-Process Product Requisition Cycle Time	The time required to provide manufacturing with a needed component, service, or additive from the time of requisition to the time of delivery.
Sourcing Costs as a % of Product Acquisitions Costs	All costs associated with the identification of potential suppliers, evaluation of RFQ's and supplier qualifications and the generation of a contract expressed as a percentage of product acquisition costs.
Staging Time	The percentage of the time that the actual stage cycle time (interval of time required for individual products to move into a temporary holding location to the time of actual shipment or movement into finished goods) complies with customer requirements.
Storage Space Utilization	Volume of all materials stored divided by the total volume of the storage facility expressed as a percentage.
Supplier Cycle Time	The time required for a supplier to complete a single cycle, beginning with the receipt of an order and ending with the fulfillment of that order.
Supplier Fill Rate	The percentage of time a supplier completes a commitment to a customer to ship or deliver an order within 24 hours.
Supplier On-Time Delivery Performance	The percentage of orders that are fulfilled on or before the original customer requested date (supplier's performance measured by the customer).
Supply Chain Finance Costs	Costs associated with paying invoices, auditing physical counts, performing inventory accounting, and collecting accounts receivable. (Does not include customer invoicing/accounting costs.)
Time and Cost related to Expediting the Sourcing Processes of Procurement, Delivery, Receiving and Transfer.	Total time and/or cost variance to standard related to expediting a product through the Total Source Cycle.
Time and/or Cost Reduction related to Expediting the Transfer Process.	Expediting cycle time for Transfer Process compared to the Standard Cycle time for the Transfer Process. Delta is the additive cost required by the disconnect.
Time and/or Cost reduction related to Source Identification	Desired State Source Identification Cycle metric compared to the As-Is State Source Identification Cycle metric. The delta being the cost /cycle improvement.
Time Interval Between a Performance Standard Request and Availability.	The time interval from the receipt of a performance standard request and the availability of the standard.
Time to Comply with Regulatory Changes	Time interval between regulatory change issuance and implementation of the change.

Total Build Time	Total build time is the average time for build-to-stock or configure-to-order products from when production begins on the released work order until the build is completed and unit deemed shippable.
Total Deliver Costs	Costs associated with the Deliver Processes including execution, administration, and planning.
Total Internal and/or External Costs That Are The Result of Inaccurate Production Rule Details	Direct and indirect costs that can be attributed to inaccurate production details. Includes rework, scrap, recalls, preparation, etc.
Total Source Cycle Time to Completion	Total elapsed time from time of requirement identification to time product is in the appropriate stocking location within the supply chain and the supplier payment is authorized.
Total Source Lead Time	Total source lead time is the cumulative lead time required to source 95% of the dollar value of materials from internal and external suppliers.
Total Supply Chain Costs	Costs associated with the supply chain including execution, administration, and planning.
Total WIP Inventory DOS	Total WIP inventory days of supply are calculated as gross WIP inventory ÷ (value of transfers/365 days).
Training/ Education	The total number of programs aimed at new work methods for experienced workers and short courses in current practices for new employees to increase productivity.
Transfer and Product Storage Costs as a % of Product Acquisition Costs	All costs associated with the storage and/or movement of the product to the next appropriate stocking location (transfer point) in the supply chain expressed as a percentage of product acquisition costs.
Transfer Cycle Time	Total elapsed time from the time the product is presented for transfer until product is moved to the next process.
Transportation Costs	Includes all company paid freight and duties from point of manufacture to end-customer or channel.
Unit Cost	Total labor, material, and overhead cost for one unit production, e.g., one part, one gallon, one pound.
Unplanned Maintenance Downtime % of total Production Time	Percent of time facilities or equipment are unavailable when scheduled compared to the Total Build Time (Production Time).
Upside Delivery Flexibility	Number of days required to achieve an unplanned sustainable 20% increase in deliveries.
Upside Installation Flexibility	Number of days required to achieve an unplanned sustainable 20% increase in installations
Upside Order Flexibility	Number of days required to achieve an unplanned sustainable 20% increase in orders.
Upside Production Flexibility	The number of days required to achieve an unplanned sustainable 20% increase in production.
Upside Shipment Flexibility	Number of days required to achieve an unplanned sustainable 20% increase in shipments.
Validation Frequency	The amount of time between reviews of a process. For example, Production Process Validation Frequency would refer to the amount of time between the reviews of the Production Process. This generally would be performed periodically to ensure that the process is generating the desired results with the desired inputs.
Value of assets provided by service provider (cost avoidance)	Value of process and/or procedure provided by a service provider that directly results in cost savings in reviewing and selecting a source.
Value-Added Employee Productivity	Value added per employee is calculated as total product revenue less total material purchases ÷ total employment (in full-time equivalents).
Verification Costs as a % of Product Acquisition Costs	All costs associated with verifying the product meets all quality and contract specifications expressed as a percentage of product acquisition costs.

Verification Cycle Time	Total elapsed time from time product starts the validation process until it moves to the next process.
Warranty and Returns	Number of returns within the warranty period. Warranty is a commitment, either expressed or implied that a certain fact regarding the subject matter of a contract is presently true or will be true.
Warranty Costs	Warranty costs include materials, labor and problem diagnosis for product defects.
Yield	The ratio of usable output from a process to its input.
Yield Variability	The condition that occurs when the output of a process is not consistently repeatable either in quantity, quality, or combination of these.

Appendix – C

Referred Cases and Articles:

For Establishment of Contextual Relations between Measures

C.1 Case, Survey and Article Reference No.

'A' stands for **Articles and News Clippings, 'S'** stands for **Surveys** and **'C'** stands for **Cases** referred**.**

Cases

Case Ref. No., Case (School, Contact person or author), 1991- 1997

[C01] **7-11 Japan** (Stanford, 1997, Seungjin Whang)
[C02] **A Note on the U.S. Transportation Industry** (HBS, 1995, Jan Hammond and J. Morrison)
[C03] **A Tale of Two Electronic Components Distributors** (HBS, 1997, Bharat Rao and Ananth Raman)
[C04] **Alden Products - European Manufacturing** (HBS, 1989/98)
[C05] **Amhall Paper Products** (Stanford, 1997, Seungjin Whang)
[C06] **Apparel Exports and the Indian Economy** (HBS, 1995, Ananth Raman),
[C07] **Apple Computer's Supplier Hubs** (Stanford, 1996, Laura Kopczak)
[C08] **Applichem** (HBS, 1986, Therese Flaherty)
[C09] **Barilla SpA** (HBS, 1994, Jan Hammond)
[C10] **Baxter Healthcare: North American Supply Chain Management Experience** (CLM, 1996, Kevin Boberg and Arnold Maltz)
[C11] **Benetton** (HBS, 1989, Howard Stevenson)
[C12] **Bose: JITII** (HBS, 1994, Roy Shapiro)
[C13] **Bradco/Taylor** (Tuck, 1999, Dave Pyke)
[C14] **Brueggers and Chesapeake Bakeries** (Duke, 1997, Gerard Cachon)
[C15] **Burlington Northern** (HBS, 1989, Jan Hammond)
[C16] **Campbell Soup: A Leader in Continuous Replenishment** (HBS, 1994, Theodore Clark)
[C17] **Cummins Engine Co: Starting up "B" Crankshaft Manufacturing at the San Luis Potosi Plant** (HBS, 1994, Robert Hayes)
[C18] **Emerson Electric Co. ACP Division: The Fan Subpack Sourcing Decision** (Darden, 1993, Keith Paige & Edward Davis)
[C19] **Ergonomics, Inc** (CLM, 1997, Omar Helferich and Robert Sroufe)
[C20] **Frito-Lay: The Backhaul Decision** (HBS, 1992, Jan Hammond)
[C21] **General Appliance** (Wharton, 1994, Morris Cohen)
[C22] **Glu Lam** (Tuck, 1993, Dave Pyke)
[C23] **H.E. Butt Grocery Company: A Leader in ECR** (HBS, 1991, Theodore Clark)
[C24] **Heineken Netherlands BV: Reengineering IS/IT to Enable Customer-Oriented Supply Chain Management** (IMD, 1997, D. Marchand, T. Vollmann, K. Bechler)
[C25] **Hewlett Packard Spokane Division: Order Fulfillment and Inventory Control** (Vanderbilt, 1995, Eric Johnson)
[C26] **HP Deskjet Printer Supply Chain** (Stanford, 1993, Hau Lee and Laura Kopczak)
[C27] **HP Universal Power Supply** (Stanford, 1997, Hau Lee)
[C28] **HP's da Vinci Project** (Stanford, 1996, Glen Schmidt, Hau Lee, Seungjin Whang)
[C29] **IBM After Sales Service** (HBS, 1995, Andrew Dutkiewicx and Jan Hammond)
[C30] **Information Flows under SAP/R3** (Stanford, 1996, Seungjin Whang and Hau Lee)
[C31] **Intercon** (HBS, 1991, K. Mishina and M. Flaherty)
[C32] **International Sourcing in Athletic Footware: Nike and Reebok** (HBS, 1994, Philip Rosenzweig)
[C33] **Kodak Business Imaging Systems Division** (HBS, 1992, Steve Wheelwright)
[C34] **Laura Ashley and Fedex Strategic Alliance** (HBS, 1996, Robert Anthony and Gary Loveman)
[C35] **LL Bean** (HBS, 1993, Arthur Schleifer)
[C36] **Massimo Menichetti** (HBS, 1988, Ramchandran Jaikumar)
[C37] **Mattel: Vendor Operations in Asia** (Vanderbilt, 1998, Eric Johnson)
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[C44] **P&G - Wal-Mart** (Darden, 1994, Mark Parry)
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[C54] **StWork** (Northwestern, 1997, David Simchi-Levi)
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[C62] **Vanity Fair Mills** (HBS, 1993, Robert Buzzell)
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HBS: Harvard Business School, Boston, CLM: Council of Logistics Management, Florida, Dartmouth College, Hanover, Northwestern University, Illinois, Darden Graduate School of Business Administration, Virginia, Duke University, Durham, Stanford University, California, Vanderbilt University, Tennessee, Wharton School. University Of Pennsylvania, Philadelphia, University of West Ontario, Canada, IMD International, Switzerland

Surveys

2003-2004

[S01] **Supplier Performance Measurement Benchmark Survey** (Aberdeen Group, 2004)
[S02] **Value Chain Survey** (IBM- BCS and Industry Week, 2003)
[S03] **Study on Supply Chain Champions** (McKinsey-University of Munster, 2004)

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Feb 2002- Feb 2006

[A01] **2004 Best Practices Awards: Bronze,** *Logistics Management,* May 1, 2004
[A02] **3 Key Software Trends,** *Logistics Management,* Mar 1, 2004
[A03] **3PL Performance Metrics: Michelin Keeps It Simple,** *Purchasing,* Jul 17, 2003
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[A06] **A Pragmatic Approach To Quality Improvement,** *Supply Chain Management Review,* May 1, 2004
[A07] **A Primer On Profitable Pricing,** *Logistics Management,* Jun 1, 2005
[A08] **A Supply-Chain Whiz Comes Back Wiser,** *Business Week,* Jun 3, 2002
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[A12] **Cessna Soars ,** *Purchasing,* Sep 4, 2003
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[A23] **Getting Serious About Carrier Performance,** *Purchasing,* Nov 6, 2003
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[A49] **Six-Sigma KOs Costs,** *Purchasing,* Mar 4, 2004
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[A71] **U.S. Postal Service Adds Services to Online Catalog,** *Purchasing,* Nov 3, 2005
[A72] **Uncertainty And The Seamless Supply Chain,** *Supply Chain Management Review,* Jul 1, 2002
[A73] **Using TCO To Rate Suppliers,** *Purchasing,* Feb 19, 2004
[A74] **Want Real Collaboration? Change Your Measures,** *Logistics Management,* Jan 1, 2003
[A75] **Ways To Measure Supplier Performance,** *Purchasing,* Mar 3, 2005
[A76] **Weighing In On Performance Measurements,** *Logistics Management,* May 1, 2002
[A77] **What Everyone Needs,** *Supply Chain Management Review,* Mar 1, 2004
[A78] **What's In A Name? ,** *Supply Chain Management Review,* Sep 1, 2004
[A79] **Why Supply Chains Must Be Strategic,** *Purchasing,* Apr 17, 2003
[A80] **Yes, Ma'am, That Part Is In Stock,** *Business Week,* Aug 1, 2005

C.2 Perspectivewise classification of Referred Cases

Case (School, Contact person or author), 1991- 1997

Innovation and Learning Perspective

[C01] **7-11 Japan** (Stanford, 1997, Seungjin Whang)
[C02] **A Note on the U.S. Transportation Industry** (HBS, 1995, Jan Hammond and J. Morrison)
[C05] **Amhall Paper Products** (Stanford, 1997, Seungjin Whang)
[C07] **Apple Computer's Supplier Hubs** (Stanford, 1996, Laura Kopczak)
[C10] **Baxter Healthcare: North American Supply Chain Management Experience** (CLM, 1996, Boberg and Maltz)
[C13] **Bradco/Taylor** (Tuck, 1999, Dave Pyke)
[C15] **Burlington Northern** (HBS, 1989, Jan Hammond)
[C19] **Ergonomics, Inc** (CLM, 1997, Omar Helferich and Robert Sroufe)
[C20] **Frito-Lay: The Backhaul Decision** (HBS, 1992, Jan Hammond)
[C24] **Heineken Netherlands BV: Reengineering IS/IT to Enable Customer-Oriented Supply Chain Management** (IMD, 1997, D. Marchand, T. Vollmann, K. Bechler)
[C28] **HP's da Vinci Project** (Stanford, 1996, Glen Schmidt, Hau Lee, Seungjin Whang)
[C30] **Information Flows under SAP/R3** (Stanford, 1996, Seungjin Whang and Hau Lee)
[C34] **Laura Ashley and Fedex Strategic Alliance** (HBS, 1996, Robert Anthony and Gary Loveman)
[C38] **Merloni Elettrodomestici SpA** (HBS, 1996, Jan Hammond)
[C41] **Nike - Global Supply Chain** (Stanford, 1998, Ann-Kristen de Verdier and Seungjin Whang)
[C49] **Rosenbluth: Supply Chain Management in Services** (Western Ontario, 1993, Allan Kamauff)
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[C57] **The Jewel Box: A Life Cycle Case Study** (CLM, 1996, Omar Helferich and Robert Sroufe)
[C60] **Toys "R" Us Japan (A&B)**(CLM, 1996, Mark Kay)
[C61] **Vandelay Industries** (HBS, 1997, David Upton)
[C63] **Walls (China) Co., Ltd**(CLM, 1997, Peter Gilmour)

Process Perspective

[C01] **7-11 Japan** (Stanford, 1997, Seungjin Whang)
[C06] **Apparel Exports and the Indian Economy** (HBS, 1995, Ananth Raman),
[C08] **Applichem** (HBS, 1986, Therese Flaherty)
[C09] **Barilla SpA** (HBS, 1994, Jan Hammond)
[C11] **Benetton** (HBS, 1989, Howard Stevenson)
[C12] **Bose: JITII** (HBS, 1994, Roy Shapiro)
[C14] **Brueggers and Chesapeake Bakeries** (Duke, 1997, Gerard Cachon)
[C16] **Campbell Soup: A Leader in Continuous Replenishment** (HBS, 1994, Theodore Clark)
[C17] **Cummins Engine Co: Starting up "B" Crankshaft Manufacturing at the San Luis Potosi Plant** (HBS, 1994, Robert Hayes)
[C18] **Emerson Electric Co. ACP Division: The Fan Subpack Sourcing Decision** (Darden, 1993, Paige & Davis)
[C21] **General Appliance** (Wharton, 1994, Morris Cohen)
[C22] **Glu Lam** (Tuck, 1993, Dave Pyke)
[C23] **H.E. Butt Grocery Company: A Leader in ECR** (HBS, 1991, Theodore Clark)
[C25] **Hewlett Packard Spokane Division: Order Fulfillment and Inventory Control** (Vanderbilt, 1995, Eric Johnson)
[C26] **HP Deskjet Printer Supply Chain** (Stanford, 1993, Hau Lee and Laura Kopczak)
[C27] **HP Universal Power Supply** (Stanford, 1997, Hau Lee)
[C31] **Intercon** (HBS, 1991, K. Mishina and M. Flaherty)
[C32] **International Sourcing in Athletic Footware: Nike and Reebok** (HBS, 1994, Philip Rosenzweig)
[C33] **Kodak Business Imaging Systems Division** (HBS, 1992, Steve Wheelwright)
[C35] **LL Bean** (HBS, 1993, Arthur Schleifer)
[C36] **Massimo Menichetti** (HBS, 1988, Ramchandran Jaikumar)
[C39] **National Bicycle** (Wharton, 1993, Marshall Fisher)
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[C63] **Walls (China) Co., Ltd**(CLM, 1997, Peter Gilmour)

Customer Perspective

[C04] **Alden Products - European Manufacturing** (HBS, 1989/98)
[C07] **Apple Computer's Supplier Hubs** (Stanford, 1996, Laura Kopczak)
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[C29] **IBM After Sales Service** (HBS, 1995, Andrew Dutkiewicx and Jan Hammond)

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[C52] **Sof-Optics** (HBS, 1991, W.E. Sasser, R. Jaikumar, D.C. Rikert)
[C54] **StWork** (Northwestern, 1997, David Simchi-Levi)
[C64] **Whelan Pharm.** (Washington Univ., 1997, Panos Kouvelis)

Financial Perspective

[C03] **A Tale of Two Electronic Components Distributors** (HBS, 1997, Bharat Rao and Ananth Raman)
[C04] **Alden Products - European Manufacturing** (HBS, 1989/98)
[C05] **Amhall Paper Products** (Stanford, 1997, Seungjin Whang)
[C07] **Apple Computer's Supplier Hubs** (Stanford, 1996, Laura Kopczak)
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C.3 Perspectivewise classification of Referred Articles & News Clippings

Feb 2002- Feb 2006

Innovation and Learning Perspective

[A17] **Despite Bigger Challenges, Buyers Show More Job Satisfaction ,** *Purchasing,* Feb 16, 2006
[A61] **The Emerging Supply Chain Management Profession ,** *Supply Chain Management Review,* Jan 1, 2006
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[A77] **What Everyone Needs ,** *Supply Chain Management Review,* Mar 1, 2004
[A74] **Want Real Collaboration? Change Your Measures ,** *Logistics Management,* Jan 1, 2003
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[A36] **Metrics Take Center Stage ,** *Logistics Management,* Jan 1, 2006
[A71] **U.S. Postal Service Adds Services To Online Catalog ,** *Purchasing,* Nov 3, 2005
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[A25] **How Dell Keeps From Stumbling ,** *Business Week,* May 14, 2001

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[A43] **Retooling The Supply Chain For Profitable Growth ,** *Logistics Management,* Oct 1, 2005
[A28] **How Procurement Excellence Creates Value ,** *Supply Chain Management Review,* Jul 1, 2005
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[A73] **Using TCO To Rate Suppliers ,** *Purchasing,* Feb 19, 2004
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[A26] **How Far Can You See? ,** *Logistics Management,* Sep 1, 2002
[A32] **HP Cuts Risk With Portfolio Approach ,** *Purchasing,* Feb 21, 2002

Appendix – D

Beamon's R-O-F Model Dimensions

Resource, Output and Flexibility

Resource

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

One general goal of supply chain analysis is resource minimization. Although a minimum level of output is often specified, the effect of reducing resources on the flexibility of the supply chain is not often considered. A supply chain may be reconfigured with reduced resources while present demands are met, but such short-term analyses do not account for the dynamic nature of demand. In this way, resources are directly related to the system's output and flexibility performance.

Output

Output measures include: customer responsiveness, quality, and the quantity of final product produced. Many output performance measures are easily represented numerically, such as: Number of items produced, Time required to produce a particular item or set of items and Number of on-time deliveries (orders). However, there are also many output performance measures that are much more difficult to express numerically, such as: Customer Satisfaction, Product quality.

A minimum level of output is often specified, although the relationship between the costs required to achieve different output levels is not generally considered. What is the added value or cost if the product is delivered early? Likewise, what are the costs if the product is delivered late? Additionally, output measures are based on short, finite time horizons, and address issues such as how many did I produce today? Not, how many can I produce tomorrow? Thus, resources affect the output of a supply chain, and the output of the supply chain system (quality, quantity, etc.) is important in determining the flexibility of the system.

Output performance measures must not only correspond to the organization's strategic goals, but must also correspond to the customers' goals and values, since strategic goals generally address meeting customer requirements. For example, a furniture manufacturer discovered that their customers actually valued delivery reliability more than fast delivery. For the customer, short lead times were secondary to having the product delivered on time. Although lead times may be extremely important to the manufacturer, on-time delivery was more important to the customer. In this case, both of these output performance measures should be utilized.

Flexibility

Some advantages of flexible supply chain systems are: Reductions in the number of backorders, Reductions in the number of lost sales, Reductions in the number of late orders, Increased customer satisfaction, Ability to respond to and accommodate demand variations, such as seasonality, Ability to respond to and accommodate periods of poor manufacturing performance (machine breakdowns), Ability to respond to and accommodate periods of poor supplier performance, Ability to respond to and accommodate periods of poor delivery performance, Ability to respond to and accommodate new products, new markets, or new competitors.

Flexibility, which is seldom used in supply chain analysis, can measure a system's ability to accommodate volume and schedule fluctuations from suppliers, manufacturers, and customers. Indeed, flexibility is vital to the success of the supply chain, since the supply chain exists in an uncertain environment. Range flexibility is defined as to what extent the operation can be changed. Response flexibility is defined as the ease (in terms of cost, time, or both) with which the operation can be changed. Although there will be a limit to the range and response flexibility of a supply chain, the chain can be designed to adequately adapt to the uncertain environment. For example, a reduction in system resources may negatively affect the supply chain's flexibility. A supply chain may be currently utilizing its resources efficiently, and producing the desired output, but will the supply chain be able to adjust to changes in, for example: product demand, manufacturing unreliability, the introduction of new products, or supplier shortages? Thus, flexibility is an important consideration in supply chain performance.

Table D.1: Measures in Transformation Dimensions of R-O-F Model
(Beamon, 1999)

RESOURCE	**Goal**: High level of Efficiency **Purpose**: Efficient resource management is critical to profitability.	**Total Cost**	Total cost of resources used.
		Distribution Costs	Total cost of distribution, including transportation and handling costs.
		Manufacturing Cost	Total cost of manufacturing, including labor, maintenance, and rework costs
		Inventory carrying cost	Costs associated with held inventory.
		Inventory Investment	Investment value of held inventory.
		Inventory Obsolescence	Costs associated with obsolete inventory; sometimes includes spoilage.
		Work-in-Process	Costs associated with work-in-process inventories.
		Finished Goods	Costs associated with held finished goods inventories.
		Return on Investment (ROI)	Measures the profitability of an organization. The return on investment is generally given by the ratio of net profit to total assets.
OUTPUT	**Goal**: High level of Customer Service **Purpose**: Without acceptable output, customers will turn to other supply chains	**Sales**	Total revenue.
		Profit	Total revenue less expenses.
		Fill Rate	Proportion of orders filled immediately
		Target Fill Rate Achievement	To what extent a target fill rate has been achieved
		Average Item Fill Rate	Aggregate fill rate divided by the number of items.
		On-Time Deliveries	Measures item, order, or product delivery performance.
		Product Lateness	Delivery date minus due date.
		Average Lateness of Orders	Aggregate lateness divided by the number of orders
		Average Earliness of Orders	Aggregate earliness divided by the number of orders
		Percent on-time deliveries	Percent of orders delivered on or before the due date.
		Back Order/Stockout	Measures item, order, or product availability performance.
		Stockout Probability	Instantaneous probability that a requested item is out of stock.
		Number of Backorders	Number of items backordered due to stockout.
		Number of Stockouts	Number of requested items that are out of stock.
		Average Backorder Level	Number of items backordered divided by the number of items.
		Customer Response Time	Amount of time between an order and its corresponding delivery.
		Manufacturing Lead Time	Total amount of time required to produce a particular item or batch.
		Shipping Errors	Number of incorrect shipments made.
		Customer Complaints	Customer Complaints Number of customer complains registered.
FLEXIBILITY	**Goal**: Ability to Respond to a Changing Environment **Purpose**: In an uncertain environment, supply chains must be able to respond to change	**Volume Flexibility**	The ability to change the output level of products produced.
		Delivery Flexibility	The ability to change planned delivery dates.
		Mix Flexibility	The ability to change the variety of products produced.
		New Product Flexibility	The ability to introduce and produce new products (this includes the modification of existing products).

Appendix – E

The Perspectives in SCOR Model:

Customer Facing, Internal Facing and Shareholder Facing

Table E.1: Perspectives of Measures in SCOR Model

Publications

Presented paper titled "Impact of Information Visibility on Productivity: A Supply Chain Perspective" in *XIII All India Input-Output Research Association (IORA) Conference* at BITS-Pilani, April 2005

VITA

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TEACHING INTERESTS:
Operations Management, Supply chain management, Management Information Systems

EDUCATIONAL QUALIFICATIONS:
Ph.D. (Supply Chain Management), BITS-Pilani, 2006 *(pursuing)*
Thesis Topic: Development of an Integrated Multi-perspective Framework for Effective Performance Measurement System in Supply Chain Management

M.Tech. (Management & Systems), IIT- Delhi, 1995
Thesis Topic: Information System Product Quality: Theoretical Precepts and Empirical Support
8.49 CGPA, 2nd Position in class

B.E. (Mechanical Engineering), IIT- Roorkee (formerly University of Roorkee), 1993
Specialization in Mechanical Vibrations
77.78% Marks, 5th position in class

TEACHING EXPERIENCE: (9 Yrs)
Lecturer, BITS-Pilani, (2003 - present)
Teaching Courses Operations Management, Supply Chain Management, Management Information Systems, Services Management System and Principles of Management to undergraduate students

Lecturer, Hindustan Institute of Management and Computer Studies-Mathura, (1998 - 2003)
Taught Courses- Operations Management, Management Information Systems, e-Commerce to post-graduate (MBA) students

Lecturer, Hindustan Institute of Science and Technology-Mathura, (1997 - 1998)
Taught Courses to B.E. (Mechanical Engineering) students

PUBLICATIONS:
Manoj Kumar Srivastava (2005), "Impact of Information Visibility on Productivity: A Supply Chain Perspective", *Proceedings of the XIII All India IORA Conference* at BITS-Pilani *(forthcoming)*

Upinder Dhar, **Manoj Kumar Srivastava**, Rajesh Jain **(2001),** "Ruby Woolens Ltd.: A case study on multiskilling", *Prestige Journal of Management and Research*, Vol. 5 No. 2, pp. 248-252

CONFERENCES / SEMINARS:

Presented Seminar on "Balanced Supply Chain Scorecard: Formulating 3rd Generation BSC for Supply Chain" at Faculty Seminar Series, Management Group, BITS-Pilani, Nov 2005

Presented Seminar on "Key Performance Measures in Supply Chain: An Evidence and Literature based Survey" at Faculty Seminar Series, Management Group, BITS-Pilani, Apr 2005

Presented paper titled "Impact of Information Visibility on Productivity: A Supply Chain Perspective" in XIII All India IORA Conference at BITS-Pilani, Apr 2005

Attended International Symposium on "Public Health Education-Indian Scenario and Challenges", organized by USUHS, Bethesda, USA at BITS-Pilani, Apr 2005

Presented Seminar on "A Conceptual Framework for Performance Measurement in Supply Chains using Interpretive Structural Modeling" at Faculty Seminar Series, Management Group, BITS-Pilani, Nov 2004

Attended National Seminar on "Challenges Posed by IPR Regimes", organized by the Research and Consultancy Division, BITS-Pilani at BITS-Pilani, Sep 2004

Attended International Conference on "Conflict Resolution: Peace and Development", organized by the Centre for International Development and Conflict management, University of Maryland, USA at BITS-Pilani, Oct 2003

Attended Intensive Teaching Workshop, conducted by Instruction Division of BITS-Pilani, Jul-Dec 2003

Attended National Conference on "Changing Business Environment: Role of Management and IT Professionals", Organized by Hindustan Institute of Management and Computer Studies-Mathura, at Agra, Feb 2003

Presented paper titled "Do We Really Need to Give up our Cultural values for the much needed Economic Development?" in the 6th National Conference of Psycho-Cultural Research Association on Individual Differences and Behavior, at Department of Psychology, Maharshi Dayanand University, Rohtak, Oct, 2002

Attended 2nd National Workshop on Case Writing at Prestige Institute, Gwalior, Dec 2001

Attended 6th National Conference of Psycho-Linguistic Association of India, Banasthali Vidyapith, Dec 2000

MDPs / WORKSHOPS / CONTACT SESSIONS:

Conducted a lecture session on the topic "Total Quality People" in MDP on "Management Excellence and Effective Branch Management" for the Officers of Bank of Rajasthan, organized by Management Group, BITS-Pilani at BITS-Pilani, Feb, 2005

Conducted four lecture sessions on TQM, MIS, Operations Management and Decision Making in "Professional Skills Development Programme" for The Junior Executive Trainees of Hindustan Zinc Ltd., Udaipur, Feb 2005

Conducted Contact Sessions of the course "Principles of Management" as the part of BS (Process Engineering) Degree, offered by Distance Learning Programme Division, BITS-Pilani for Employees of CFCL at Kota, Jul-Dec 2005 and for the BS (Software Engineering) Degree for Wipro Trainees at Delhi, Jan-May 2005

Conducted Contact Sessions of the course "Principles of Management" and "Essentials of Project Management" as the part of BS (Power Engineering) Degree, offered by Distance Learning Programme Division, BITS-Pilani for Junior Engineers of NTPC India at Kahalgaon and Korba Centres, May 2003 and at Singrauli and Vindhyachal Centres, July-Dec 2004

Online Lectures delivered through video conferencing in the course, Management Information Systems for the Distance Learning Programme Division, BITS-Pilani in three semesters, Jul-Dec 2004; Jan-May 2005 and Jul-Dec 2005

Online Lectures delivered through video conferencing in the course, Principles of Management for the Distance Learning Programme Division, BITS-Pilani, Jan-May, 2006

Assisted in an MDP on "Team Building and Conflict Management" for middle level managers, as facilitator in two case sessions, organized by Hindustan Institute of Management and Computer Studies-Mathura at Agra, Dec 1998

Assisted in a "Management Sensitization Programme" for Senior Doctors as a student-coordinator, organized by Department of Management Studies, IIT-Delhi, at PGI, Chandigarh, Jan 1995

THESIS / PROJECTS SUPERVISION:

Supervised 4 First Degree Thesis of undergraduate students in the areas SCM, KM and CRM at BITS-Pilani, 2004-2005

Supervised 5 Higher Degree Thesis of post-graduate students in the areas e-commerce, CRM and Information Systems at HIMCS, Mathura, 1998-2003.

Supervised 6 Practice School-I Projects (summer training) of undergraduate students of BITS-Pilani, at LML Ltd, Kanpur, May-Jun 2003

Supervised 31 Study Oriented Projects and Computer Oriented Projects for the undergraduate students of BITS-Pilani.

OTHER PROFESSIONAL ACTIVITIES

Paper Setter for various courses in Ph.D. Qualifying Examinations of Research and Consultancy Division of BITS-Pilani

Paper Setter for various courses in End Semester Examinations of MBA Programme for Dr. Ambedakar University, Agra

Editor of the Monthly Newsletter, "*Between the Lines*" published by Management Group, BITS-Pilani

Process Owner for the establishment and development of Data Analysis Lab at Management Group, BITS-Pilani

MBA Programme Coordinator in Hindustan Institute of Management and Computer Studies-Mathura, 1998-2003

Development of an
Integrated Multi-Perspective Framework for Effective Performance Measurement System in Supply Chain Management

REPORT

Submitted in partial fulfilment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY

by
Manoj Kumar Srivastava

Under the Supervision of
Prof. Anil K Bhat

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE
PILANI (RAJASTHAN)
2006

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Report

A. Relevance of the Developed SCPM Framework

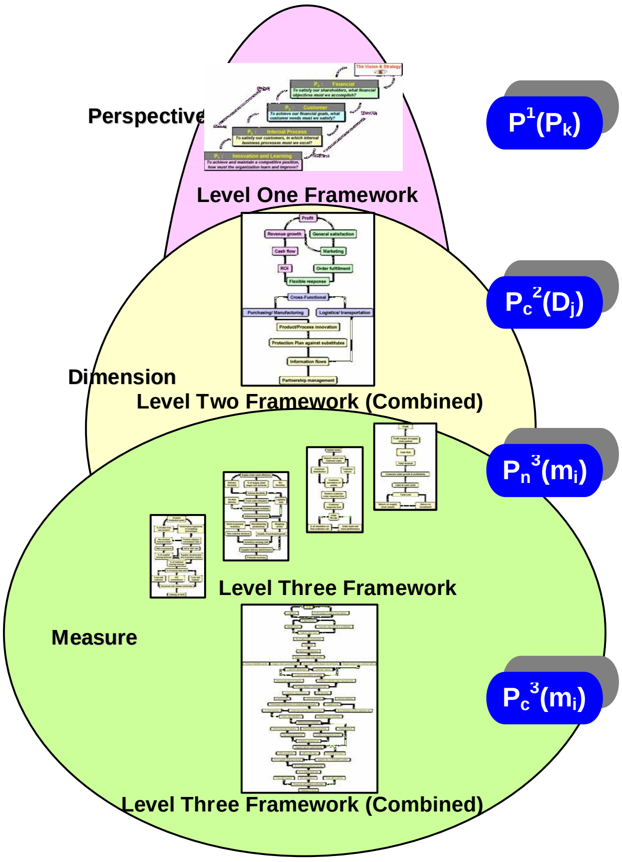
1. This research is an attempt to **extend** the Balanced Supply Chain Scorecard (BSCS) concept of Brewer & Speh (2000) by developing an ISM (Interpretive Structural Modeling)-based Integrated BSCS. The Strategy Map framework of Kaplan and Norton (2000) is taken as the basis for the Level one construct of the developed framework, where all the four perspectives (Innovation and Learning, Process, Customer and Financial) constitute a hierarchical configuration.

2. Further identifying dimensions in each perspective, Level Two construct of the developed framework configures all supply chain performance dimensions according to their influence and dependence power. This construct has crucial managerial implications for improving supply chain efficiency. These identified dimensions are **representing** each perspective to a major extent. Thus managerial efforts in improving these dimensions will improve the concern perspective.

3. Level Two construct of the framework is primarily for the **top management level** whose interest is more in the summarized version of responsible critical success factors. By establishing causal relationships between supply chain performance dimensions, the framework presents a picture where the top management is able to know how the organizational strategic initiatives may be **aligned** with that of their supply chain specific strategic initiatives as a member of the chain.

4. ISM based model for supply chain dimensions is predominantly following the configuration as depicted by Strategy Map. Focus on innovation and learning-centric dimensions leads to improvement in process-centric dimensions which in turn improve customer-centric dimensions. At the top there is improvement in finance-centric dimensions, because of this improvement in customer-centric dimensions. Though there is some overlapping in the order of these dimensions, as they do not follow the pattern of strategy map strictly, still they suggest a **systematical strategic order** of managerial **initiatives**, a manager must follow to get maximum results out of all efforts made. Though the strength of causality in this framework is not calculated for each contextual relationship, dependence and influence power graph in MICMAC analysis reflect a lot of decisional value

5. Level Three construct of the newly developed framework, configures supply chain performance measures. The four ISM based models developed for each perspective present highly focused implementation guidelines for **middle level managers**. The primary purpose behind these constructs is to zeroed down on the perspective alone. In order to improve individual perspective, the measures in that perspective must be targeted accordingly. Every measure is mapped on influence-dependence graph to identify the degree of managerial interventions. Each of these models is of much concern for managers in the area of finance, marketing, operations and human resources. Though these managers are not directly responsible for the supply chain performance improvement, their directional concerns in their domain specific measures contribute a lot for overall performance of supply chain. The developed models are exclusive in the sense that they keep individuality of the perspective intact, but simultaneously suggest managers to **align their efforts** in a manner that whole chain is benefited. These configurational adjustments in performance improvement plan according to contextual relations between measures make a significant cumulative impact on supply chain performance. Thus contextual relations established in this research are necessary proposition for getting optimized supply chain performance.



6. Development of ISM based model for all supply chain measures taken simultaneously, irrespective to their perspectivewise classification represents a holistic view of supply chain performance system. This Level Three construct has its strength in its totality. As this construct is generic in nature, any member of the chain may apply it. The weightage and the appropriateness of each measure or contextual relationship may vary, but their contextual positioning is progressively suggestive in nature. The **operational level managers** must know the directional impact of their performance enhancement efforts for any measure. This pre-hand knowledge will equip them more effectively to work in synchronization with the efforts of other departments / divisions / supply chain members. This harmony at the operational level will improve the performance locally as usual, but at the same time will also regulate other higher end measures due to the inherent contextuality, which is relating them with each other. This directional linkage depicted with degree of influence makes all mangers in supply chain to pool their performance improvement efforts towards chain optimization-a key objective of an excellent supply chain performance measurement system.

B. Usefulness of the Framework in Specific Contexts *(Illustrations)*

This section of the report attempts to justify five ISM based models by applying it in an industry-specific context. Scattered initiatives are already taken by supply chain members in these examples. The new framework systematizes these initiatives and suggests guidelines for their alignment in a sequence that will optimize the overall performance of the supply chain.

Strategic Managerial Implications (for Top Level Management)

7. *Applying Level Two Framework $P_c^2(D_j)$ in Pharmaceutical Supply Chain[1]: an example*

With a rising tide of counterfeit and mispriced drugs, pharmaceutical companies are turning to information sharing technologies to better track medications through a convoluted supply chain. The partnership between chain members to go for track-and-trace accountability **(information flows)** solution adapted by pharmaceutical companies gave chance to formulate **protection plan against** these **substitutable** (counterfeit) products. This protection plan generated need of a **process innovation** in which drug wholesalers were supposed to provide a paper "*pedigree*," or record of where drugs originated from. Holograms, color-shifting inks, tamper-resistant packaging tape and watermarks were introduced in response to the need of protection plan as part of the **manufacturing** dimension in process perspective. Information flows regarding maintenance of prescribed temperature make **logistics / transportation** activities to meet these standards. Refrigeration facility, fast delivery and inventory halts are planned accordingly. **Cross-functional coordination** will improve due to improvement in measures of purchasing/manufacturing, process innovation and logistics/transportation dimensions. The technology, sales and project inputs must be forged synergistically so that response is flexible enough to meet dynamic demands. The counterfeit and mispriced drug chains can be competed by overcoming volume and time constraints. If the right quantity of genuine drug is available at the pharmacy at right time (which needs a great **flexibility in response**), the order will be fulfilled in the way customer wants it. This leads to general **customer satisfaction** and later on supports formulation of better **marketing plans.** These consciously made plans will lead to more **profit**.

The solution discussed here for pharmaceutical supply chain can be managed more effectively, if MICMAC analysis is used. By considering relative influence and dependence power of each dimension, pharmaceutical supply chain members may focus on high influence power variables. In this case partnership management, information flows and protection plan against counterfeit drugs (i.e. providing a paper "*pedigree*," or record of where drugs originated from, and sharing and imbibing this solution as a practice across whole supply chain) are the high influence power variables*****, cumulatively affecting 40/118=34% of all possible leading (driving) contextual relations. Also each dimension in this

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[1] ***Inputs from:*** *Susannah P. (2006), "Cracks in the Pharmaceutical Supply Chain", CIO Magazine, Jan 15*

** Here **Variable** is a general term used for referring Dimension or Measure. It refers to either one of them in a model accordingly.*

cluster is affecting thirteen (87%) other dimensions of the perspective. These variables are differing marginally in their dependence power, which is due to contextual relationship among themselves. Second cluster (focus on manufacturing, process innovation and logistics) in this case is having 31/118=26% of all possible leading (driving) contextual relations and on average each dimension affects ten (69%) other dimensions. Thus together they are responsible for more than half of all driving contextual relations. Thus managerial efforts (at top management level, for this framework) must be around these independent variables. In turn 60% system improvement will come through the improvements in these variables. The order of the efforts and the extent of effort-impact on other performance variables are two major outcomes of the framework.

Domain Specific Managerial Implications (for Middle Level Management)

ISM based model developed for individual perspective provides guidelines for perspective-specific initiatives. The middle level managers in their domain must know the sequence and relative focus-extent of performance improvement efforts, in order to get improved perspective. The summarized account of these perspective-specific initiatives is given below.

8. *Applying Level Three Framework $P_1^3(m_i)$ in Amusement Park[2]: an example*

For a supply chain where Innovation and learning perspective is number one priority, for example **entertainment service industry** (like amusement park, event organization, theme tourism), this perspective must be focused meticulously in order to get strategic alignment with efforts in other perspectives. Drawing major inferences from the level three framework $P_1^3(m_i)$, the highest level variable- product finalization point (that means delivering the service to the recipient at the appropriate point, both in space and in time) will be the outcome of efforts, mainly targeted at the independent variable cluster in its MICMAC analysis. 56% of all possible leading (driving) contextual relations are affected by the improvement in these six measures. Also on average each one of these variables is affecting thirteen (81%) other variables in this model. The specific managerial interventions for each of these variables are discussed below:

- **Training on SCM**: *It is about making staff aware regarding the positioning, relevance and fit value of their work in entire spectrum of the chain -in this case of amusement park, safety locks in rides are having certain strength and operational features, how they are engineered, what possible implications they are having on financial penalties levied due to any mishappening etc., are some very crucial facts, every concerned person must know. The future implications of these small issues on overall supply chain functioning must be the agenda of training program.* **Personnel with related certificate:** *The qualified workforce with exposure to those operational and strategic impact visions makes a major difference in innovating the chain.*

- **EDI transactions** and **% of shared data-sets** *the supply chain is enriched by the speed at which information flow takes place across the supply chain. The data interchanged about anything (be it safety, be it manufacturing, be it customer preferences or supplier capabilities) makes every person more aware about relevance and implications of his activity. This increased transaction of datasets will reduce the opacity of the chain. In this*

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[2] ***Inputs from:*** *Bullmore, J. (2000), "Alice in Disneyland: A Creative View of International Advertising", In: Jones, J.P. (ed.) International Advertising, Realities and Myths. Thousand Oaks, CA: Sage.*

amusement park example, timing of the attractions must be synchronized in a manner such that visitors are not overcrowding any particular workstation, yet the workstation is full of optimal number of visitors. This balance typically demands a lot of integration at various cross-functional levels. EDI is the only answer for this much needed integration. Managers must plan to increase % of data sets shared and should assess the efficacy of any unit's involvement in the process. People must be encouraged to share the data, in order to get the same. This two-way sharing will lead to more innovative idea-generations and higher rate of effective implementations.

- **Trust with Customer** and **Supplier** *these two variables represent conscious efforts towards involving customer and supplier in supply chain design process. The innovation and learning perspective must draw factual data from the horse's mouth itself. Visitor's choice survey, design your own ride, feedback coupons are some of the initiative to incorporate customer voice. Suppliers on the other hand must try to match the design and manufacturing requirements based on these customer voices. Color, shape, design, aesthetics, speed and fear-factor must be embedded in a typical design of any attraction point at the amusement park and this needs total trust and involvement from supplier side. The experience of customer should be recorded in its progressive spirit. Trust here implies valuing the customer's voice, making it visible and later on drawing pride and responsibility when it is translated into design. Customer feels pride, when his suggestions are translated in the design and they are visible. Then, he actively participates in sharing the responsibility also. Managers must exploit this, as it is the key to get innovation from those who want it the most.*

The innovation project team must focus on these six variables due to their extent (56%) of affecting all other efforts in this perspective. The leading contextual relationships modeled in this perspective will guide mangers to know the outcome of their efforts in advance.

9. *Applying Level Three Framework $P_2^3(m_i)$ in Automotive Supply Chain[3]: an example*

Process perspective translates innovation and learning efforts into design features by incorporating changing environmental needs. Automobile industry is one of the most suited examples in this category where process improvements are at top priority. ISM based model developed in this research provides a very useful methodological guideline for operations managers. The process improvement and reengineering them in response to the innovation-intense market, both demand a careful look on *what* actually improves *what*. Based on MICMAC analysis for this perspective, many important managerial implications can be drawn. Interestingly eight variables are responsible for 69% leading contextual relationships existing in this process perspective. Also on average each one of these variables affects other thirteen (74%) variables. Thus a disciplined attempt to improve these measures will affect process perspective to a larger extent.

- **Forecast accuracy**: *uncertainty due to "length of the chain" & "information invisibility" make prediction of any demand pattern difficult, yet it is one of the biggest challenges in front of supply chain managers. Recent technological advancements may somewhat reduce this uncertainty, but what is more needed is its precise assessment. Decision support tools are must for managers to assist in understanding the costs, benefits, and risks associated with various alternatives. The innovation and learning perspective (discussed previously- trust, sharing, EDI etc.) also provides progressive support towards achieving this accuracy.*

- **Supplier delivery performance** *is a measure which affects time component of all other major process elements. The managers are focusing on fundamental shift in supplier's orientation that is moving from a focus on sales*

[3] ***Inputs from***: ** www.catlogistics.com/ & *Meier, R.L., Williams, M.R. and Singley, R.B. (2004), "Supply Chain Management: Strategic Factors From The Buyers' Perspective", Journal of Industrial Technology, Volume 20, Number 2*

to focus more on 'end-customer satisfaction'. More and more suppliers must measure their own delivery performance. The associated variables in this regard may be not-right-first time, delivery schedule adherence, time-productivity and overall equipment effectiveness on supplier side.

- **Inventory carrying cost, Raw material stockouts,** and **Work-in process inventory** *these all variables concerned with inventory handling affect the highest level measure (supply chain cycle efficiency) in this model. They delay all other pipeline processes if not managed effectively. To make cost-effective supply chain, it is imperative for individual members to be lean. Sometimes, raw material stockouts also mean that inventory is having undesired raw material. Flexibility in volume and mix (variables at the top portion of the model) can be dealt only when there is a proper action plan for managing work-in-process inventory.*

- **Quality of purchased goods** *this variable implies that the manufacturability will only be translated according to the customer voice, if quality of purchased goods meets the desired standard. The transitiveness of this variable is one of the major constraints, as bad quality is not easily visible. Manufacturing department tries to amend and compromise with this attribute, as it seems more easy-going for them to correct quality problems at their level, rather than insisting and expecting the same from suppliers. But this reduces manufacturing productivity and affects schedule variance. Purchase norms should be strictly conveyed to the suppliers, so that even they understand* ***what*** *is expected from them and* ***why****?*

- **Manufacturing Productivity** *though it is one of the obvious measures in process perspective, its specificity in supply chain continuum should be understood. The productivity here implies being in tandem to the flow of the chain. What counts most is the gain in productivity at the receiving end of the chain. Component manufacturers, outsourcing units, export and import divisions, resource planning heads…they all are equally responsible stakeholders in this productivity campaign.*

The process perspective is the most visible and tangible performance domain in supply chain. The dependent variables in the ISM based model make foundation for the customer perspective later on. Hence these managerial initiatives, well within the control of individual member, must be thoroughly discussed by/among all inter-organizational players. The mutual trade-off among members to vector their efforts will result in better flexibility (all three, volume, mix and delivery) & cycle efficiency, without duplicating efforts in continuum of the chain.

10. *Applying Level Three Framework $P_3^3(m_i)$ in Healthcare Supply Chain[4]: an example*

Customer perspective is the performance-view of the chain from customer's side. This customer-facing characteristic of measures is complex and difficult to sense. Still it is the existential-essence of all supply chain channels. ISM based model and its MICMAC analysis reveal that 58% leading contextual relationships are directly or indirectly influenced by just four variables in this perspective. Also eight (83%) variables in this model are affected by each such variable. These driving variables are only effective when a harmonious effort-pooling is done in these customer related issues. The objective is to retain existing customers and maximizing market share by adding new customers to the repeat sales. These four variables are discussed elaborately next, to understand the complexity of customer perspective. The human element is involved in this perspective to its maximum extent, so managers must understand their preferences, grievances, expectations and patience-limit.

[4] ***Inputs from****: Modell, S. (2004), "Performance Measurement Myths in the Public Sector: A Research Note", Financial Accountability & Management, Vol. 20, No. 1, pp. 39-55.*

- **% of resolution on first customer call**: *first impression is the last, and resolution must be done on first call, whether it is the order call, complaint call or after sales service call. "Timely delivery" and "customer response time" are two important performance variable to get a satisfied customer. This "resolving at first call" needs a lot of integration available at the table of call receiver, before it is resolved. Whom to consult, who is responsible, who should be informed are some fundamental questions to be answered before committing anything to customer. Marketing manger should try to establish this problem resolution universal-helpdesk. The backend designing of this helpdesk is based on inputs from various sources, but integrated in real-time. In health care system, the emergency cases, resolved after second customer call are catastrophic, both to the customer and to the chain.*

- **Order Track and Trace Performance**: *keeping track of the service rendered, their potential impacts, efficacy of the medication, prescription timing and enforcement methodology are some of the issues demanding flawless tracking and traceability in health care services. The client specific tracking is one of the challenges in this sector. Error margin is very low. And remedial measures are very much dependent on streak by streak mapping of the service supply chain. Service provider will be more effective, if this tracking and traceability element is embedded in the process by default. For precision in traceability and tracking, customer care department must work jointly with the service delivery system designer.*

- **Order fill rate**: *Use substitute services, make business continuation plans, crash activities or go for resource rescheduling, but meet committed order fill rate. Any dip in this measure changes customer perception of service quality of healthcare system. The low order fill rate will delay the response rendered to customer and will result in customer dissatisfaction. Managers must treat this measure as one of the key variable. The action-plan to improve order-fill rate is industry-specific, but a proper tracking and tracing system is no doubt an essential prerequisite and applicable to most of the industries.*

- **Customer response time**: *Behavioral scientists agree that the average waiting time of customers for any service has reduced drastically. No longer are customers ready to wait after certain threshold limit and even this threshold limit is squeezing. Responding within expected time is must, and supply chain dynamics in healthcare services is no exception. Patients are not bothered that the hospital is overcrowded or doctors are busy, the response must be immediate. Analysis of customer psychology reveals that this promptness in response must not necessarily be in the final service, but even the support services, which are rendered immediately, conveys the signal that they (customers) are treated empathically. Though customer satisfaction is not only dependent on this response rate, but indeed it improves customer perception of service quality and results in customer returns (repeat sales).*

In this example, because of customer's involvement being integral to the perceived quality, it is difficult to manage measures of customer perspective. But meeting that challenge differentiates a world-class service provider from the average one. (Be it Amazon.com, Dell, Sony or British Airways). The other dependent variables in this model are ultimately leading towards improved market share. The influence-extent of these four independent variables is very high, thus mangers must target them first and should understand their contextual impact accordingly.

11. *Applying Level Three Framework $P_4^3(m_i)$ in Food Supply Chain [5]: an example*

Financial perspective was always the primary concern for the managers, but Strategy Map shows that, it is more a dependent perspective. The ISM based model and MICMAC analysis in this perspective identify four measures to improve financial flow in supply chain. The extent of their

[5] ***Inputs from***: *Eastham, J., Sharples, L., and Ball, S. (2001), "Food Supply Chain Management: Issues for the Hospitality and Retail Sectors", Butterworth-Heinemann, London, UK*

involvement out of all prevailing contextual relationships is 67%. On average each variable is also having impact on other eight (86%) variables. Thus supply chain managers involved in its financial dynamics must understand the implication and contextual impacts of these variables.

- **Return on supply chain assets** *this measure tells whether supply chain assets are meeting financial return to the expected extent or not. Supply chain is not recorded for asset utilization, as a whole, but it must be. This overall asset utilization is significant for chain's overall financial efficiency. Partnership based on trust is the key. Innovative efforts towards asset pooling and link-to-link synchronization will result in higher financial gains.*

- **Return on investment:** *Internationalization of the food supply chain and different trade practices across political regions are new challenges in this supply chain example and any investment to make supply chain smoother must return its value. The supply chain must assess utility-gain of any investment and should trace its impact-magnitude trail on financial flow, both on upstream and downstream side. Return in this context may not necessarily be financial in short term, but strategically, they must speak financial dialect.*

- **Total cost***: As a whole total cost involved in achieving supply chain objectives must be cost- effective. This total cost calculation is not merely the sum of individual costs. Total cost must also include time stamp associated with each instance of cost involvement. That way it will reflect the time value of every rupee invested. Thus upstream costs, incurred in comparative past must be translated in the present value term when added to downstream costing. Sometimes the time lag, geographic and political variations, stringency of meeting quality norms are diverging so much, that total cost calculation, based on just summation of individual costs is misleading.*

- **Cash-to-cash cycle***: It is time lag between payment done for getting resources and the payment received from the user. Shorter it is, more agile is the chain. The working capital, as prime-mover of the supply chain activities, is generated because of this cycle. If link-to link cycle is dyadically efficient, it will pull the flow of cash towards revenue generation and ultimately in increasing profit.*

These measures are having mostly direct impact on other dependent variables, which is a unique feature of this perspective. Only one transitive contextual relation is there. This implies that the route of improving financial measures is very rigid and supply chain managers in this domain must strictly follow the sequence. The profit as ultimate financial measure will be more only when every other lower level variable is improved at the level, where it resides.

C. Unique Feature of the Framework *(Generic Operational Level Model, $P_c^3(m_i)$)*

The unique feature of the developed framework is the ISM model developed by taking measures (53) from all perspectives simultaneously and establishment of contextual relationships, by structurally modeling them. As input is taken from a pool of supply chain examples in meta-research methodology (which were characteristically different due to variations in their product, region, policy, customer, structure, and technology), the model is generic to a larger extent. Though its validity is not discussed for different supply chains (which is one of the limitations of this research), still the variables pattern resembles with the order followed in Strategy Map. Some interpretations and managerial implications are listed below to guide supply chain managers and designers. These points are customizable according to the nature of supply chain in question, but the clusters will be positioned more or less at the level where they are stationed in the model. Based on MICMAC analysis and the configuration of variables in Figure 4.7 at page 149 of thesis, the clusters, with their relative leading contextual strength are discussed below:

12. The cluster comprising ***Trust among suppliers/customers, Training, EDI transactions, Certified Personnel*** measures has 258/1462=17% impact extent out of all leading contextual relationships. This cluster appears at the lowest level in the structured model. On average these five variables affect fifty-two (97%) other variables in the entire model. Thus Training and Trust-building must be at the top priority for supply chain performance improvement initiatives.

13. The next cluster of four measures, namely ***Supplier development, Forecast sharing by supplier/customer*** and ***Data sharing*** has 187/1462=12% impact extent out of all leading contextual relationships. On average every measure in this cluster is affecting forty-seven (89%) other variables. Thus information sharing for better prediction purposes must be the next objective of managers, when they have trained personnel and established trust with suppliers. These efforts in training and trust-building will also build culture of sharing in the interest of the whole chain.

14. Third cluster comprising ***Forecast accuracy, VMI/CRP*** and ***R&D investment*** implies smoothness in material flow, by accurately predicting demand & involving vendors in inventory-management. The trust previously built, will help towards this VMI initiatives. Establishment of vendor rating system through an exhaustive survey will reduce inventory carrying and managing cost. Altogether this cluster affects 132/1462=9% out of all leading contextual relationships. On average every measure in this cluster is affecting forty-four (83%) other variables.

15. Fourth cluster in this model is mainly associated with ***Inventory, Quality*** and ***Delivery performance*** on upstream side. These material-stock related issues affect manufacturing schedule performance at in-stream supply chain part. These four measures have 11% extent of all leading contextual relationships and on average each of these measures is affecting forty (75%) other supply chain performance variables. After calculating VMI/CRP ratio, managers must set order-winning norms (time, quality and cost) for suppliers.

16. Fifth cluster consisting **Work-in-process inventory, Manufacturing productivity, Shipping errors**, **Adherence-to-schedule** builds a workable premise at downstream side of the supply chain for meeting schedule and quality demand of customers. Shipping errors, a very common error in supply chains, may jeopardize all critical & excellent quality efforts, made at upstream side. This cluster is having extent of leading contextual relationships as 10%. On average each of these measures is affecting thirty-six (68%) other supply chain performance variables. These measures are having immediate proximity to at least six regulating variables in this ISM based model. Managers should understand this unique feature of the cluster, as regulating variables are responsible for desirable tuning of the system. The power and proximity of these variables to affect regulating variables demand more careful attention, if later on, system has need to re-engineer some of its characteristics.

D. General Contributions

The research develops six ISM models in its attempt for an integrated multi-perspective framework. The general contributions are accounted below:

17. Integration

The framework has its strength in its integration of supply chain measures according to managerial levels. The strategic metric set (dimensions) and operational metric set (multi-perspective measures) are integrated with tactical metric set (measures in individual perspective). Thus all three managerial levels may visualize what other managerial levels are targeting and in which order. This shared picture of destination-stops synchronizes managerial efforts made to improve supply chain performance.

The integration of inter-organizational efforts is another feature of this research. Chain members may look this integration either perspective-wise or incrementally. For example, transportation services and manufacturing unit may target initially only on innovation and learning perspective. The effort-pooling by both in this perspective may later on initiate improvement process perspective. These in-tandem improvements in performance measures have many-fold impact on overall health of the supply chain. Other way, the incremental integration efforts may be planned by distributing efforts. Each member should identify his mix of measures from different perspectives to focus more on them. For this, all participating members must discuss leading contextual relations together vis-à-vis prevailing flow of the chain. Downstream members must focus more on customer and financial measures and upstream members on innovation and process measures. This discussion will prepare a mix of measures from different perspectives (not necessarily from only a single perspective) each member will go for improving. But other members must also be aware to their partner's *mix*. The objective of building seamless supply chain is possible only, if efforts are towards welfare of the whole chain.

18. Totality

The measures and dimensions identified by extensive literature review in this research are representing a comprehensive supply chain performance measurement system. Majority of the supply chain performance issues are covered in this attempt. Discussion on various researchers' contribution in identifying these measures is fused together with Balanced Scorecard framework in supply chain context. Second generation performance measurement frameworks are discussed for deriving motivation behind contextual orientation among supply chain performance measures. Strategy Map, with its four hierarchically configured perspectives, is a well established framework for performance improvement in general. Breaking these perspectives into dimensions and further into measures, extends the totalitarian characteristic of BSC to the micro level. This totality attribute of the framework, of encompassing nearly all possible performance issues in supply chain (by the very nature of BSC framework) make mangers to focus, more on ***how*** aspect, rather than ***which*** aspect of the efforts.

19. Contextual Dyads

The relationships established in structural modeling are the base for identifying leading & lagging characteristic of each variable. This characteristic provides effort-directionality to all managerial strategies, towards improving supply chain performance. The contextual dyads may further be established between different variables (of different perspectives) across individual organizations. These contextual dyads will map inter-organizational contextuality, which is very useful for formulating shared strategic initiatives. Though this attempt is not made in the research and only those measures are considered, which by their own definition, involve two or more organizations of the chain, efforts should be made in this direction. Shared strategic initiatives will enrich supply chain to larger extent and depth.

E. Specific Contributions

The specific contribution of the research is due to its MICMAC analysis for each of the six models. According to improvement need, felt by the managers, they may target their efforts in two ways:

20. Level-centric approach

One of the ways in which ISM models and their respective MICMAC analysis can be used is to zero-in on any level first and identifying variables residing at this level. The influencing strength (of this cluster of variables at this level) in terms of percentage of the numbers of variables it is affecting, represents how much important this level is in whole schema. The influence strength may also be calculated in terms of percentage of all leading contextual relationships covered by the variables at this level. Both ways the identified importance of the level will assist managers to align their efforts cumulatively. The level just below and just above this level are analytically very important for managers, as these immediate neighborhood levels depict the first apparent cause & impact of their local efforts.

21. Variable-centric approach

Another way to improve supply chain performance is by focusing on any measure first. MICMAC analysis will supplement the chosen measure with its influencing power. The ISM model will tell about immediate neighbors of this variable (either affecting or affected by). The contextual relationships, immediate neighbors and influence power of each variable, altogether portray a complete target plan for the performance variable in focus. This approach is based on manager's intuition and system's need, in contrast to the approach based on management-level. The research implies that managers must understand the chords connected to any variable and if feel, must refer to the level, where it can be handled more effectively.

F. System Implications

Research portrays two system implications for managers, namely system stability and variable classification in MICMAC analysis. They suggest managers, how they must proceed in a controlled order. In today's rapidly changing techno-social environment, system development, system maintenance and its further functional improvement are of great concern to the managers. System must be stable enough to sustain random environmental *threats* and it is very important for managers to identify & focus on those factors which are responsible for strengthening or weakening the system. Research discusses these system implications on two broad features of the framework:

22. Variable Classification

MICMAC analysis classifies variables in five categories and managers get a clear understanding of variable's impact on system stability. This is relevant for aligning individual system with organizational objectives and strategies. The independent and regulating variables have relatively more influence power and reflect efforts which are ***essential*** and ***desirable*** for system improvement. The autonomous variables are not having any significant impact on system performance or stability. Managers must also know these out-line variables and their insignificant impact power, if at all they have considered them in their performance improvement initiatives. Their redundancy may save a lot of managerial time and effort. The linkage variables, having boomerang effect and causing system to be fragile must be understood very well. These performance variables must be worked out to get a further sub-division, so that their high dependency on themselves is not presenting circularity in cause-effect relation. Dependent variables on other hand are result variables that explain what managers will get out of so much effort. Rationality of knowing outcomes, both in qualitative and positioning term will make managers more clear about their line of action.

23. Customizability

The framework has customizability feature in its very design. Every supply chain is not the same and unique characteristics of any supply chain must be incorporated effectively, in any performance framework. The supply chain performance action plan for individual supply chain depends upon some crucial attributes, like product type, corporate strategy, outsourcing strategy etc. Few perspectives, dimensions and hence measures are not as relevant as they are, in other supply chains. For example, functional and innovative product supply chains differ in their attributes a lot.[6] *Customer response time* is more critical in the supply chain for an innovative product, but *repeat versus new customer sale* is more critical for the supply chain for a functional product. Likewise the *trust with customer* is more critical in functional product, but the *trust with supplier* is more critical for innovative product. The framework permits supply chain designers to incorporate these attributional differences through its sensitivity analysis, where relative strength of dependence and influence will alter variable's position on MICMAC graph. Though customizability is not very much fluid in its range of accommodating attributional differences, still it reflects these changes at a visible decisional level.

Thus this research extends supply chain balanced scorecard framework by structurally modeling the measures both at individual and cumulative level, while keeping BSC perspectives at its core. Thus it is a sincere effort towards developing an effective supply chain performance system. Managers may find it relevant for translating organizational strategy into actionable targets, in an integrative and multi-perspective manner. The contextuality among variables lay down a solid foundation of making seamless supply chain. Now the chain can be optimized globally, by aligning all individual efforts by the very design of supply chain performance measurement system itself.

[6] ***Inputs from:*** *Yoo, J.S., Park, J.H. and Lee, J.K. (2004), "Effect of Product Type on Designing Balanced Supply Chain Scorecard", PACIS (Pacific-Asian Conference on Information System), Shanghai, China*