A Thesis Report on

"STRUCTURAL MODELING AND INTEGRATIVE ANALYSIS OF SUPPLY CHAIN USING SYSTEMS APPROACHES".

Submitted in partial fulfillment of the requirement for the award of degree of

MASTER OF ENGINEERING
IN
PRODUCTION AND INDUSTRIAL ENGINERING

Submitted By:-
Ashish Kumar Kaushal
Regd. No. 801082003

Under the guidance of:-

Dr.V.P.Agrawal,
Visiting Professor, MED,
Thapar University Patiala,
Patiala-147004, Punjab

DEPARTMENT OF MECHANICAL ENGINEERING
THAPAR UNIVERSITY, PATIALA-147001, INDIA

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ACKNOWLEDGMENT

It is a matter of immense pleasure to acknowledge my debt revered teacher and supervisor **Dr.V.P.Agrawal,** Visiting Professor Department of Mechanical Engineering Thapar University Patiala. It is because of his priceless intellectual guidance, innovative and constructive ideas for having given me complete independence, affectionate encouragement to put my desire and thought, which paved the way for the successful completion of this work. It is indeed my privilege to work under him.

I also feel very much obliged to **Dr.Ajay Batish** Professor and Head of the department of mechanical engineering Thapar University Patiala for giving me the opportunity to work on this industrial application project.

Deep heartedly I thank my **parents** and my family members for their encouragement, blessings and motivation at each and every step.

Last, but not the least, I thank **god** for giving me strength to overcome difficulty and having showers of his blessings always on me. JAI SHRI RAM.

(Ashish Kumar Kaushal)

CERTIFICATE

I hereby certify that he work which is being presented in the thesis entitled, **"Structural Modeling and Integrative Analysis of Supply Chain using Systems Approaches"**, In partial fulfillment of the requirements for the award of degree of Master of Engineering in Production and Industrial Engineering submitted in Mechanical Engineering Department of Thapar University Patiala, is an authentic record of my own work carried out under the supervision of *Dr. V.P.Agrawal*.

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

Kaushal
12/07/12
(Ashish Kumar Kaushal)

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

(Dr. V.P.Agarwal),
Supervisor,
Visiting Professor,
Mechanical Engineering Department,
Thapar University Patiala,
Punjab-147004

Countersigned by

(Dr.Ajay Batish),
Professor & Head,
Mechanical Engineering Department,
Thapar University Patiala,
Punjab-147004

(Dr.S.K.Mohapatra)
Dean, Academic Affairs,
Thapar University Patiala
Punjab-147004

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ABSTRACT

The purpose is to integrate supply chain analysis to obtain system-wide optimized solutions and to increase the increase the level of comprehensiveness of the supply chain modeling and to develop method of characterization of supply chain management on its structure**.** Elements constituting the supply chain management and the interactions between them have been identified through a literature survey and have been represented by graph based model. The matrix models and the variable permanent function models are developed for carrying out decomposition, characterization and the total analysis. The cause and effect diagrams are also prepared to analyze the effect of every factor on the supply chain performance. Structural patterns and combination sets of subsystems interacting in various ways have been recognized as capabilities of manufacturing system matrix has been proposed as a systematic technique for structural analysis of supply chain. Also the terms of permanent multinomial characterize the supply chain uniquely and are highly useful for computational storage, retrieval, communication as well as analysis of the structural information of supply chain. Cause and effect provides in detail all the causes which are responsible for a particular effect. Six sigma and quality function deployment ensures a quality to be built maintained at every step of the product manufacturing and warns also if any goes beyond the specified limits. Application of the proposed model in analyzing supply chain based on customer sensitivity and risk alleviation has been carried out. Through the use of proposed methodology, a manager will be able to make better informed decisions towards organizational efforts of improving the productivity and speed. For aiding several decisions, different"what-if"scenario may be generated with several structural modifications. This graph theory based methodology is a novel mechanism to seamlessly integrate manufacturing system wide optimization. This paper is an attempt to address the need for comprehensive and integrated analysis of the supply chain system. Cause and effect analysis provide the blueprints of the factors affecting the supply chain the most and there causes and severity to the system.

Design for studying the influence of inter-organizational integration on business performance, and design of supply chain for x-abilities using graph theoretic approach and cause and effect analysis and concurrent engineering approach has been carried out. Design for a supply chain system requires multidisciplinary knowledge. A designer should consider product lifecycle issues as well as selection of supplier and inter-organizational integration and manufacturing strategies simultaneously at conceptual stage without missing any information. The proposed methodology concurrently considers all the x-abilities/design aspects along with interactions without missing any information and hence leads to a high quality product and high level of customer satisfaction and increased business performance. A methodology which combines concurrent design concepts, graph theory, matrix algebra and permanent multinomial is proposed. Abilities namely integration, quality, reliability, manufacturing, performance, inter-organizational integration, ICT and the design parameters under each x-ability are identified. The design index derived is useful for researcher and designer in evaluating the conceptual design alternatives.

Keywords:-System analysis, modeling, performance management, graph theory, supply chain, cause and effect, X-ability, concurrent engineering, MADM.

Chapter 1

Introduction

1.1).OVERVIEW OF SUPPLY CHAIN

A Supply Chain encompasses all activities in fulfilling customer demands and requests as shown in Figure 1.1. These activities are associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information and funds flows. There are four stages in a supply chain: the supply network, the internal supply chain (which are manufacturing plants), distribution systems, and the end users. Moving up and down the stages are the four flows: material flow, service flow, information flow and funds flow. E-procurement links the supply network and manufacturing plant, e-distribution links the manufacturing plant and the distribution network, and e-commerce links the distribution network and the end users. The supply chain begins with a need for a computer. In this example, a customer places an order for a Dell computer through the Internet. Since Dell does not have distribution centers or distributors, this order triggers the production at Dell's manufacturing center, which is the next stage in the supply chain. Microprocessors used in the computer may come from AMD and a complementary product like a monitor may come from Sony. Dell receives such parts and components from these suppliers, who belong to the up-stream stage in the supply chain. After completing the order according to the customer's specification, Dell then sends the computer directly to the users through UPS, a third party logistics provider. This responsive supply chain is illustrated in Figure 1.1. In this supply chain, Dell Computer is the captain of the chain; the company selects suppliers, forges partnerships with other members of the supply chain, fulfills orders from customers and follows up the business transaction with services . This is an efficient supply chain and is illustrated in Figure 1.1.These two different types of supply chain, responsive supply chain and efficient supply chain, will be discussed in detail.

Supply Chain Management is a set of synchronized decisions and activities utilized to efficiently integrate suppliers, manufacturers, warehouses, transporters, retailers, and customers so that the right product or service is distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying customer service level requirements. The objective of Supply Chain Management (SCM) is to achieve sustainable competitive advantage. A company's supply chain in an e-Biz environment can be very complicated. Figure 1.2 illustrates a simplified supply chain because many companies have hundreds and thousands of supplies and customers. The supply chain in Figure 1.2 includes internal supply chain functions, an upstream supplier network, and a downstream distribution network. Logistic function facilitates the physical flow of material from the raw material producer to the manufacturer, to the distributor, and finally, to the end user.

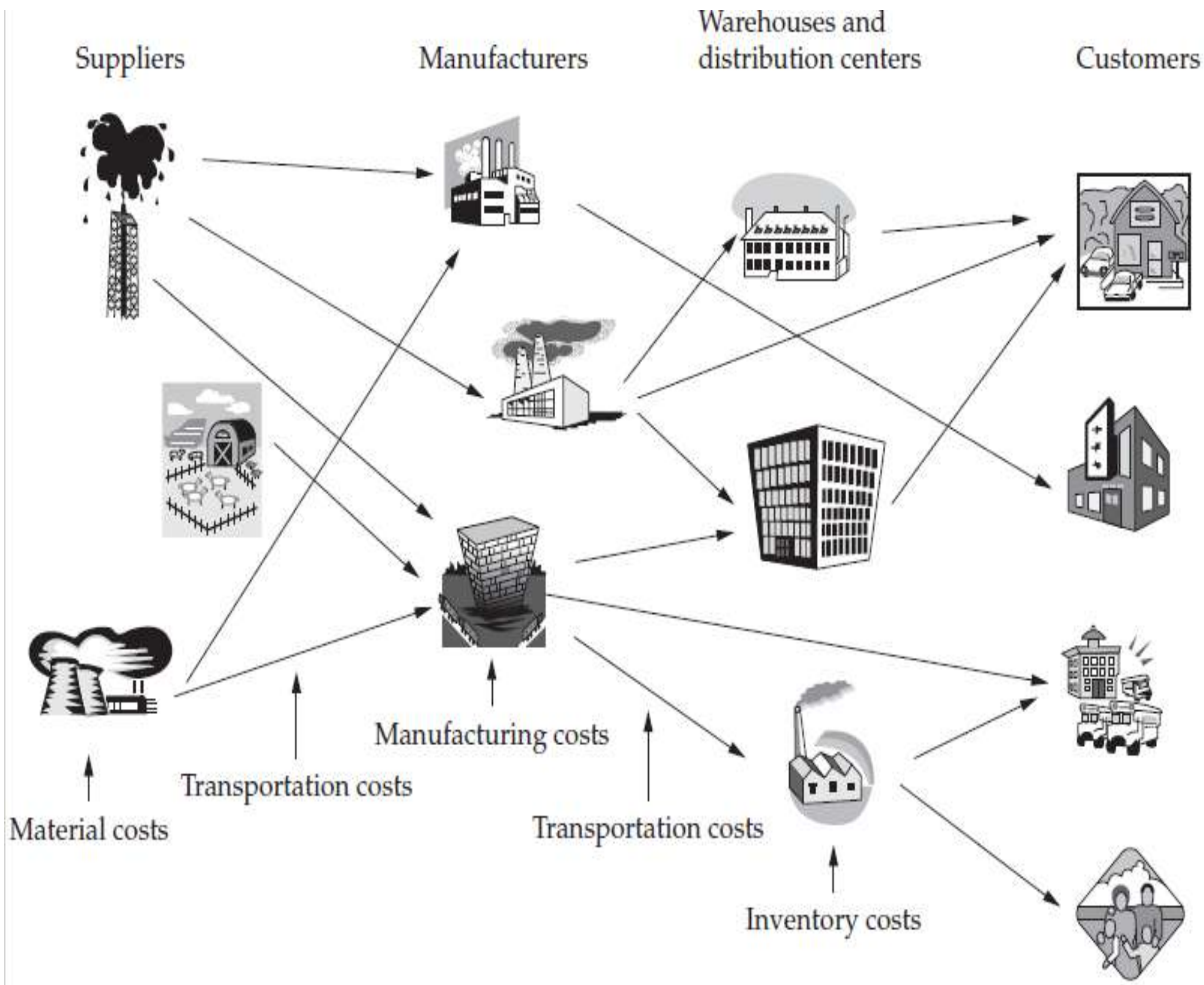

Fig.1.1. The logistics network
(An introduction to supply chain management by Sunil chopra, Peter meindl, D.v.johns Pearson's publication)

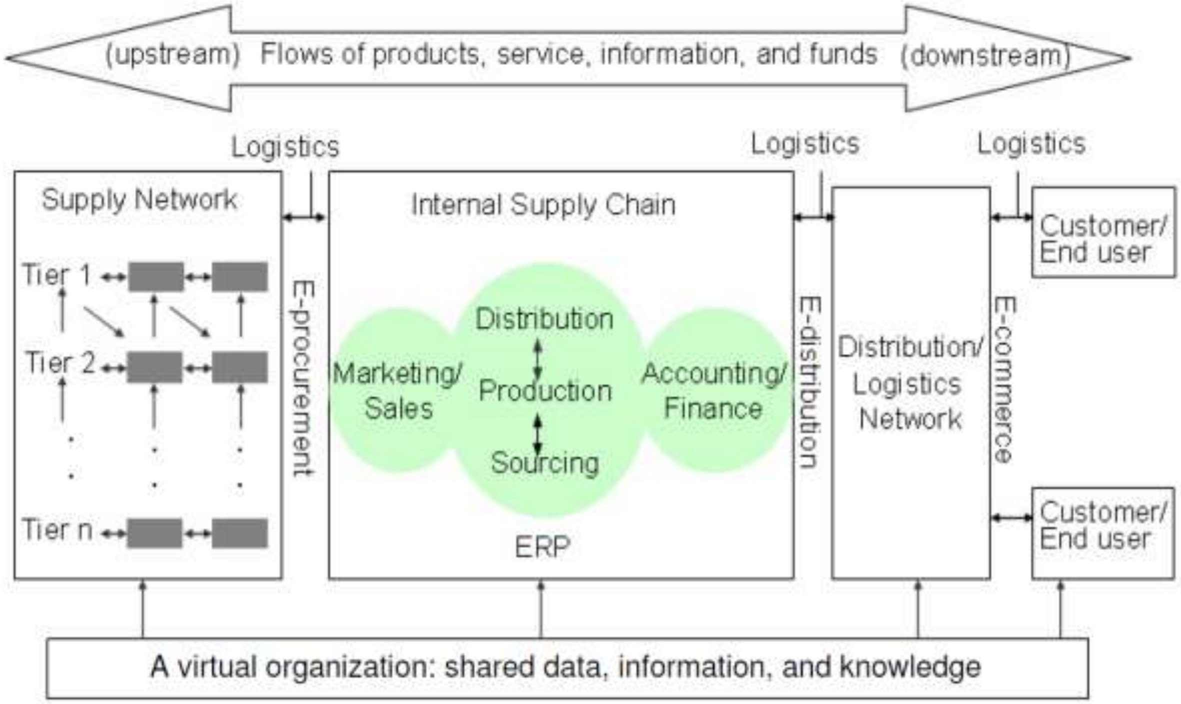

Fig.1.2. Supply chain in E-business environment

The ***internal supply chain*** of the focal manufacturing company in the middle of Figure 1.2 includes sourcing, production, and distribution.

Sourcing or purchasing of the company is responsible for selecting suppliers, negotiating contracts, formulating purchasing process, and processing order.

Production is responsible for transforming raw materials, parts or components to a product.

Distribution is responsible for managing the flow of material and finished goods inventory from the manufacturer to customer. Enterprise Resource Planning systems (ERP) integrate the entire company's information system, process and store data, cut across functional areas, business units, and product lines to assist managers make business decisions. As an IT infrastructure, ERP influences the way companies manage their daily operations and facilitates the flow of information among all supply chain processes of a firm.

The ***supplier network*** on the left-hand side of Figure 1.2 consists of all organizations that provide materials or services, either directly or indirectly. For example, a computer manufacturer's supplier network includes all the firms that provide items ranging from such raw materials as plastics, computer chips, to subassemblies like hard drives and motherboards. A supplier of motherboard, for example, may have its own set of suppliers (*second-tier suppliers*) that provide inputs that are also part of the supply chain.

The ***distribution network*** on the right-hand side of Figure 1.2 is responsible for the actual movement of materials between locations. Distribution management involves the management of packaging, storing, and handling of materials at receiving docks, warehouses, and retail outlets. A major part of distribution management is transportation management, which includes the selection, and management of external carriers or internal private fleets of carriers.

E-commerce uses advanced technology to assist business transactions in a web-based environment and facilitates the transaction of information flow and fund flow. E-commerce involves business-to business transaction (B2B) such as Covisint, business-to-customer transaction such as Amazon.com (B2C), customer-to-business transaction (C2B) such as priceline.com, and customer-to-customer transaction (C2C) such as e-Bay auction. E-commerce is conducted via a variety of electronic media. These electronic media include electronic data interchange (EDI), electronic funds transfer (EFT), bar codes, fax, automated voice mail, CD-ROM catalogs and a variety of others.

E-distribution instructs where to locate the sources of supply and advises how to access them, as well as how to move the materials to the retailers via the Internet or a web-based environment.

E-procurement is a part of E-commerce. E-procurement completely revolutionizes a manufacturing or distribution firm's supply chain, making a seamless flow of order fulfillment information from manufacturer to supplier.

Now we have characterized the nature of supply chain management, we are ready to make a few relevant points:

1. The role of supply chain management is to produce products that conform to customer requirements.
2. The objective of supply chain management is to be efficient and cost-effective through collaborative efforts across the entire system.
3. The scope of supply chain management encompasses the firm's activities from the strategic level through the tactical and operational levels since it takes into account the efficient integration of suppliers, manufacturers, wholesalers, retailers, and end users.

1.2 Supply Chain Management in an E-Biz Environment

Virtual Integration – A New growing Trend

Virtual integration is to use technology and information to blur the traditional boundaries among suppliers, manufacturers, distributors, and end users in a supply chain. Today, the virtual corporation of various firms in a supply chain is a reality with suppliers and customer trading over the Internet in real-time to create maximum value. Virtual integration offers the advantage of tightly coordinated supply chain that has traditionally come through vertical integration. In the age of virtual organizations, managers, engineers, professional staff, and technical workers are no longer the lone custodians of the corporate knowledgebase. Knowledge is shared across cultural-boundaries, time-boundaries, and space-boundaries to create strategic frontiers in global and virtual enterprises. A seamless virtual integration of firms within a supply chain requires real-time automation of inter-organization business processes that span across trading partners. In the last decade, organizations involved in a supply chain use e-mail, faxes, and voice mail. These practices introduce delays and often require data to be re-entered multiple times. The increase in productivity in the late 90s is a direct result of computer technology. Organizations view their suppliers and customers as adversaries who are not to be trusted. This prevents entry into successful long-term relationships. Performance is often narrowly viewed and procurement decisions are often based solely on price. Relationships are viewed in terms of a zero-sum game where there is a clear winner and a clear loser. The integrated supply chain includes joint improvement projects, training seminars, workshops, and meetings between organizations' top management. As the degree of communication increases between customers and suppliers, higher levels of informal information sharing are witnessed. A step ahead of integrated supply chain is virtual integration, which blurs the walls of supply chain organizations. The trend of mass-customization forces many companies to focus on their core competences, and outsource a wide range of functions including design, manufacturing, and distribution. This trend drives the need for a virtually integrated supply chain.

1.3 An Evolution: From Material Management to Supply Chain Management

Information technology is the key driving force for moving material management to supply chain management in the second half of the 20thcentury. The stages of the business model evolution are illustrated in Figure 1.3, with Bill of Materials (BOM) processor in the early 60s, Material Requirement Planning (MRP) in the 70s, Manufacturing Resource Planning (MRPII) in the 80s, Enterprise Resource Planning (ERP) in the 90s, and supply chain management (SCM) packages in the early twenty-first century. The impact in the evolution of advanced technology and computer power on materials and supply chain management is phenomenal. In the early 1960s, a BOM processor was written on a 1400 disk computer in Milwaukee. In mid 1960, the first use of the computer for planning material was introduced and was named MRP. IBM was the first to introduce MRP software to the market. The significance of MRP is that it identifies what product is required by the customer; compares the requirement to the on-hand inventory level and calculates what items need to be procured and when. By itself, MRP does not recognize the capacity limitation. It will schedule order release even when the capacity is not available. Closed loop MRP was then introduced to include capacity requirement planning as a part of material requirement planning.

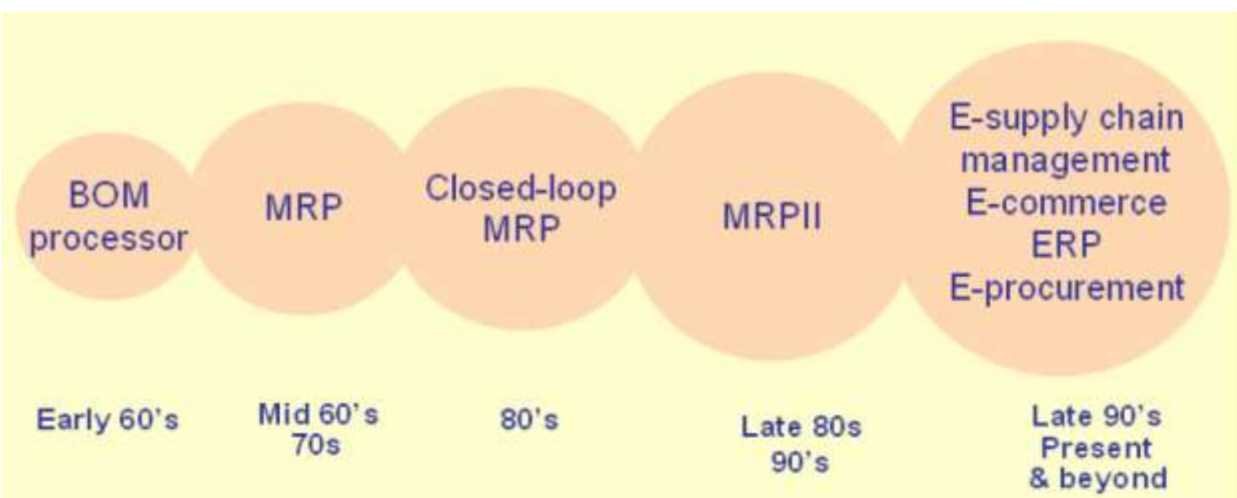

Fig.1.3. Evolution of e-supply chain

Advancement of computer capacity makes the extra mathematical computations for capacity planning available and affordable. In the Mid 80's, Manufacturing Resource Planning (MRPII) evolved out of MRP and closed loop MRP. MRPII is a method for the effective planning of all resources of a manufacturing company. MRPII closed the loop not only with the capacity planning and accounting systems but also with the financial management systems. Consequently, all the resource of a manufacturing company could be planned and controlled as the information became more accessible using MRPII. In the 1980s, labor cost decreased and material cost increased due to the automation of production process. Reducing inventory and shortening lead-time became inevitable to survive the competition. Companies searched for new business paradigms that would lead to competitive advantage. Just in Time (JIT), Theory of Constraints (TOC) and Total Quality Management (TQM) are examples of strategies that helped companies to improve production processes, reduce costs and successfully compete in a variety of business environments. The late 80s and early 90s witnessed the shift of 'time to market."Customers demanded to have their products delivered when, where, and how they wanted them. JIT requires cooperation along the entire supply chain with the ultimate goal of maximizing the profit of the supply chain. The beginning of JIT started along the assembly line and was not necessarily controlled by a computer but by a Kanban card using pull the overall value generated rather than profit generated in a particular supply chain.

1.4 Supply Chain Management Models

1.4.1 Competitive priorities and manufacturing strategy

The ability of a supply chain to compete based on cost, quality, time, flexibility, and new products is shaped by the strategic focus of the supply chain members. A firm's position on the competitive priorities is determined by its four long-term structural decisions: facility, capacity, technology, and vertical integration, as well as by its four infrastructural decisions: workforce, quality, production planning and control, and organization. The cumulative impact of infrastructural decisions on a firm's competitiveness is as important as long-term structural decisions. Manufacturing strategy focuses on a set of competitive priorities such as cost, quality, time, flexibility, and new product introduction. It classifies production processes to five major types: project, job shop, batch, line, and continuous flow. "Make-to-stock", "assemble-to order", "build-to-order" and "engineer-to-order" are a few of the manufacturing strategies used to address competitive priorities to compete on the market place. Make-to-stock involves holding products in inventory for immediate delivery, so as to minimize customer delivery times. This is in the category of push system. Demand is forecasted and production is scheduled before demand is there. Assemble-to-order is the strategy to handle numerous end-item configurations and is an option for mass-customization. Assemble-to order items use standardized parts and components. They require efficient and low cost production in the fabrication process and flexibility in the assembly or configuration stage to satisfy individualized demand from customers. Build-to-order, on the other hand, produces customized products in low volume after the manufacturer receives the orders. Build-to-order items are usually in very small volumes and require high technical competency, high product performance design, and effective due date management. Engineer-to-order produces products that are with unique parts and drawings required by customers. Product volume is very small and typically is one-of-a-kind in a job-shop environment. The cycle time from order to delivery is usually long because of the unique customization nature. MRP planning is extremely important for engineer-to-order.

1.4.2 Efficient supply chain and responsive supply chain

One of the causes of supply chain failure is due to the lack of understanding of the nature of demand. The lack of understanding often leads mismatched supply chain design. Fisher (1997) suggested two distinctive approaches, efficient supply chain and responsive supply chain, to design a firm's supply chain. The purpose of responsive supply chain is to react quickly to market demand. This supply chain model best suites the environment in which demand predictability is low, forecasting error is high, product life cycle is short, new product introductions are frequent, and product variety is high (Table 1.1). The responsive supply chain design matches competitive priority emphasizing on quick reaction time, development speed, fast delivery times, customization, and volume flexibility. The design features of responsive supply chains include flexible or intermediate flows, high-capacity cushions, low inventory levels, and short cycle time. The purpose of an efficient supply chain is to coordinate the material flow and services to minimize inventories and maximize the efficiency of the manufacturers and service providers in the chain. This supply chain model best fits the environment in which demands are highly predictable, forecasting error is low, product life cycle is long, new product introductions are infrequent, product variety is minimal, production lead-time is long and order fulfillment lead-time is short. The efficient supply chain design matches competitive priority emphasizing on low cost operations and on-time delivery. The design features of efficient supply chain include line flows, large volume production, and low capacity cushions.

S.No.	Factor Under Consideration	Efficient Supply Chain	Responsive Supply Chain
1.	Reaction to market demand	Slow	Quickly
2.	Forecasting error	Low	High
3.	Demand predictability	High	Low
4.	Product life cycle	Long	Short
5.	Product life cycle and New product development	Minimal/Slow	High/Frequent

Table (1.1):-Comparative study of Efficient and Responsive supply chains.

1.5 Global Optimization of the Supply Chain

What makes finding the best system wide, or globally optimal, integrated solution so difficult? A variety of factors make this a challenging problem:

1. The supply chain is a complex network of facilities dispersed over a large geography, and, in many cases, all over the globe.

2. Different facilities in the supply chain frequently have *different, conflicting objectives.* For instance, suppliers typically want manufacturers to commit themselves to purchasing large quantities in stable volumes with flexible delivery dates. Unfortunately, although most manufacturers would like to implement long production runs, they need to be flexible to their customers' needs and changing demands. Thus, the suppliers' goals are in direct conflict with the manufacturers' desire for flexibility. Indeed, since production decisions are typically made without precise information about customer demand, the ability of manufacturers to match supply and demand depends largely on their ability to change supply volume as information about demand arrives. Similarly, the manufacturers' objective of making large production batches typically conflicts with the objectives of both warehouses and distribution centers to reduce inventory. To make matters worse, this latter objective of reducing inventory levels typically implies an increase in transportation costs.

3. The supply chain is a dynamic system that evolves over time. Indeed, not only do customer demand and supplier capabilities change over time, but supply chain relationships also evolve over time. For example, as customers' power increases, there is increased pressure placed on manufacturers and suppliers to produce an enormous variety of high-quality products and, ultimately, to produce customized products.

4. System variations over time are also an important consideration. Even when demand is known precisely (e.g., because of contractual agreements), the planning process needs to account for demand and cost parameters varying over time due to the impact of seasonal fluctuations, trends, advertising and promotions, competitors' pricing strategies, and so forth. These time-varying demand and cost parameters make it difficult to determine the most effective supply chain strategy, the one that minimizes system wide costs and conforms to customer requirements. Of course, global optimization only implies that it is not only important to optimize across supply chain facilities, but also across processes associated with the development and supply chains. That is, it is important to identify processes and strategies that optimize, or, alternatively, synchronize, both chains simultaneously.

1.6 Managing Uncertainty and Risk

Global optimization is made even more difficult because supply chains need to be designed for, and operated in, uncertain environments, thus creating sometimes enormous risks to the organization.

A variety of factors contribute to this:

1. Matching supply and demand is a major challenge: (Business-Magazines)

a. Boeing Aircraft announced a write-down of $2.6 billion in October 1997 due to "raw material shortages, internal and supplier parts shortages and productivity inefficiencies . . ."].

b. “Second quarter sales at U.S. Surgical Corporation declined 25 percent, resulting in a loss of $22 million. The sales and earnings shortfall is attributed to larger than anticipated inventories on the shelves of hospitals”.
c. “EMC Corp. said it missed its revenue guidance of $2.66 billion for the second quarter of 2006 by around $100 million, and said the discrepancy was due to higher than expected orders for the new DMX-3 systems over the DMX-2, which resulted in an inventory snafu”.
d. “There are so many different ways inventory can enter our system it’s a constant challenge to keep it under control” [Johnnie Dobbs, Wal-Mart Supply Chain and Logistics Executive].
e. “Intel, the world’s largest chip maker, reported a 38 percent decline in quarterly profit Wednesday in the face of stiff competition from Advanced Micro Devices and a general slowdown in the personal computer market that caused inventories to swell”.
Obviously, this difficulty stems from the fact that months before demand is realized, manufacturers have to commit themselves to specific production levels. These advance commitments imply huge financial and supply risks.
2. Inventory and back-order levels fluctuate considerably across the supply chain, even when customer demand for specific products does not vary greatly. To illustrate this issue, consider Figure 1.1-1.3, which suggests that in a typical supply chain, distributor orders to the factory fluctuate far more than the underlying retailer demand.
3. Forecasting doesn’t solve the problem. Indeed, we will argue that the first principle of forecasting is that “forecasts are always wrong.” Thus, it is impossible to predict the precise demand for a specific item, even with the most advanced forecasting techniques.
4. Demand is not the only source of uncertainty. Delivery lead times, manufacturing yields, transportation times, and component availability also can have significant supply chain impact.
5. Recent trends such as lean manufacturing, outsourcing, and off shoring that focus on cost reduction increase risks significantly. For example, consider an automotive manufacturer whose parts suppliers are in Canada and Mexico. With little uncertainty in transportation and a stable supply schedule, parts can be delivered to assembly plants “just-in-time” based on fixed production schedules. However, in the event of an unforeseen disaster, or weather-related calamities, adherence to this type of strategy could result in a shutdown of the production lines due to lack of parts.
Similarly, outsourcing and off shoring imply that the supply chains are more geographically diverse and, as a result, natural and man-made disasters can have a tremendous impact.
Although uncertainty and risk cannot be eliminated variety of models, methods, algorithms have been generated in the literature which illustrates how product design, network modeling, information technology, procurement, and inventory strategies are used to minimize uncertainty, and to build flexibility and redundancy in the supply chain in order to reduce risks.

1.7) Graph Theory

Graph theory may be said to have its beginning in 1736 when EULER considered the (general case of the) **Königsberg bridge problem**: Does there exist a walk crossing each of the seven bridges of Königsberg exactly once? (Solutio Problematis ad geometriam situs pertinentis, *Commentarii Academiae Scientiarum Imperialis Petropolitanae* 8 (1736), pp. 128-140.)
It took 200 years before the first book on graph theory was written. This was “Theorie der endlichen und unendlichen Graphen” (Teubner, Leipzig, 1936) by KÖNIG in 1936. Since then

graph theory has developed into an extensive and popular branch of mathematics, which has been applied to many problems in mathematics, computer science, and other scientific and not-so-scientific areas. There are no standard notations for graph theoretical objects. This is natural, because the names one uses for the objects reflect the applications. Thus, for instance, if we consider a communications network (say, for email) as a graph, then the computers taking part in this network are called nodes rather than vertices or points. On the other hand, other names are used for molecular structures in chemistry, flow charts in programming, human relations in social sciences, and so on.

1.8) Graphs and their plane figures

Let V be a *finite* set, and denote by
$E(V) = \{\{u, v\} \mid u, v \in V, u$ 6= $v\}$. The **2-sets** of V, i.e., subsets of two distinct elements.
DEFINITION. A pair $G = (V, E)$ with $E \subseteq E(V)$ is called a **graph** (**on** V). The elements of V are the **vertices** of G, and those of E the **edges** of G. The vertex set of a graph G is denoted by VG and its edge set by EG. Therefore $G = (VG, EG)$. In literature, graphs are also called *simple graphs*; vertices are called *nodes* or *points*; edges are called *lines* or *links*. The list of alternatives is long (but still finite).
A pair $\{u, v\}$ is usually written simply as uv. Notice that then $uv = vu$. In order to simplify notations, we also write $v \in G$ and $e \in G$ instead of $v \in VG$ and $e \in EG$.
For a graph G, we denote
$nG = |VG|$ and $nG = |EG|$.
The number nG of the vertices is called the **order** of G, and nG is the **size** of G. For an edge $e = uv \in G$, the vertices u and v are its **ends**. Vertices u and v are **adjacent** or **neighbors**, if $uv \in G$. Two edges $e1 = uv$ and $e2 = uw$ having a common end, are **adjacent** with each other.
A graph G can be represented as a plane figure by drawing a line (or a curve) between the points u and v (representing vertices) if $e = uv$ is an edge of G.
Often we shall omit the identities (names v) of the vertices in our figures, in which case the vertices are drawn as anonymous circles. Graphs can be generalized by allowing **loops** vv and **parallel** (or **multiple**) **edges** between vertices to obtain a **multigraph** $G = (V, E, y)$, where $E = \{e1, e2, . . . , em\}$ is a set (of symbols), and $y: E \to E(V) \cup \{vv \mid v \in V\}$ is a function that attaches an unordered pair of vertices to each $e \in E$: $y(e) = uv$. Note that we can have $y(e1) = y(e2)$.
We also study **directed graphs** or **digraphs** $D = (V, E)$, where the edges have a direction, that is, the edges are ordered: $E \subseteq V \times V$. In this case, uv 6= vu. The directed graphs have representations, where the edges are drawn as arrows. A digraph can contain edges uv and vu of *opposite directions*.
Graphs and digraphs can also be coloured, labelled, and weighted.
A function $a: VG \to K$ is a **vertex colouring** of G by a set K of colors. A function $a: EG \to K$ is an **edge colouring** of G. Usually, $K = [1, k]$ for some $k \geq 1$.
If $K \subseteq \mathbf{R}$ (often $K \subseteq \mathbf{N}$), then a is a **weight function** or a **distance function**.

Isomorphism of graphs

DEFINITION. Two graphs G and H are **isomorphic**, denoted by $G \sim= H$, if there exists a bijection $a: VG \to VH$ such that
$uv \in EG \Longleftrightarrow a(u)a(v) \in EH$ for all $u, v \in G$.

Hence G and H are isomorphic if the vertices of H are renaming of those of G. Two isomorphic graphs enjoy the same graph theoretical properties, and *they are often identified*. In particular, all isomorphic graphs have the same plane figures (excepting the identities of the vertices).
A graph has usually many different adjacency matrices, one for each ordering of its set VG of vertices. The following result is obvious from the definitions.
Theorem 1.1. *Two graphs G and H are isomorphic if and only if they have a common adjacency matrix. Moreover, two isomorphic graphs have exactly the same set of adjacency matrices.*
Graphs can also be represented by sets. For this, let X = {$X1$, $X2$, . . . , Xn} be a family of subsets of a set X, and define the **intersection graph** GX as the graph with vertices $X1$, . . . , Xn, and edges $XiXj$ for all i and j (i 6= j) with $Xi \cap Xj$ 6= Æ.
Theorem 1.2. *Every graph is an intersection graph of some family of subsets.*
Proof. Let G be a graph, and define, for all $v \in G$, a set
$Xv = \{\{v, u\} \mid vu \in G\}$.
Then $Xu \cap Xv$ 6= Æ if and only if $uv \in G$. ⊓⊔
Let $s(G)$ be the smallest size of a base set X such that G can be represented as an intersection graph of a family of subsets of X, that is,
$s(G) = \min\{|X| \mid G$ ∼=
GX for some X ⊆ $2X\}$
How small can $s(G)$ be compared to the order nG (or the size nG) of the graph. It was shown by KOU, STOCKMEYER AND WONG (1976) that it is algorithmically difficult to determine the number $s(G)$ – the problem is NP-complete.

Degrees of vertices

DEFINITION. Let $v \in G$ be a vertex a graph G. The **neighborhood** of v is the set $NG(v) = \{u \in G \mid vu \in G\}$.
The **degree** of v is the number of its neighbors:
$dG(v) = |NG(v)|$.
If $dG(v) = 0$, then v is said to be **isolated** in G, and if $dG(v) = 1$, then v is a **leaf** of the graph. The **minimum degree** and the **maximum degree** of G are defined as
$d(G) = \min\{dG(v) \mid v \in G\}$ and $D(G) = \max\{dG(v) \mid v \in G\}$.
The following lemma, due to EULER (1736), tells that if several people shake hands, then the number of hands shaken is even.

Sub graphs

Ideally, given a nice problem the local properties of a graph determine a solution. In these situations we deal with (small) parts of the graph (subgraphs), and a solution can be found to the problem by combining the information determined by the parts. For instance, as we see, the existence of an Euler tour is very local, it depends only on the number of the neighbors of the vertices.
DEFINITION. A graph H is a **sub graph** of a graph G, denoted by $H \subseteq G$, if $VH \subseteq VG$ and $EH \subseteq EG$. A sub graph $H \subseteq G$ **spans** G (and H is a **spanning sub graph** of G), if every vertex of G is in H, i.e., $VH = VG$. Also, a sub graph $H \subseteq G$ is an **induced sub graph**, if $EH = EG \cap E(VH)$. In this case, H is **induced** by its set VH of vertices. In an induced sub graph $H \subseteq G$, the set EH of

edges consists of all $e \in EG$ such that $e \in E(VH)$. To each nonempty subset $A \subseteq VG$, there corresponds a unique induced sub graph

$G[A] = (A, EG \cap E(A))$.

To each subset $F \subseteq EG$ of edges there corresponds a unique spanning sub graph of G, $G[F] = (VG, F)$. Is the sub graph of G obtained by removing (only) the edges $e \in F$ from G. In particular, $G-e$ is obtained from G by removing $e \in G$. Similarly, we write $G + F$, if each $e \in F$ (for $F \subseteq E(VG)$) is added to G. For a subset $A \subseteq VG$ of vertices, we let $G-A \subseteq G$ be the sub graph induced by $VG \setminus A$, that is, $G-A = G[VG \setminus A]$, and, *e.g.*, $G-v$ is obtained from G by removing the vertex v together with the edges that have v as their end.

Paths and cycles

A discrete graph is 0-regular, and a complete graph Kn is $(n - 1)$-regular. In particular, $\#Kn = n(n - 1)/2$, and therefore $\#G \leq n(n - 1)/2$ for all graphs G that have order n.

Many problems concerning (induced) subgraphs are algorithmically difficult. For instance, to find a maximal complete sub graph (a sub graph Km of maximum order) of a graph is unlikely to be even in NP.

Walks

DEFINITION. Let $ei = uiui+1 \in G$ be edges of G for $i \in [1, k]$. The sequence $W = e1e2 \dots ek$ is a **walk of length** k **from** $u1$ **to** $uk+1$. Here ei and $ei+1$ are compatible in the sense that ei is adjacent to $ei+1$ for all $i \in [1, k-1]$.

We write, more informally,

W: $u1 \longrightarrow u2 \longrightarrow \dots \longrightarrow uk \longrightarrow uk+1$ or W: $u1$

$k \longrightarrow uk+1$

Write $u \longrightarrow v$ to say that there is a walk of some length from u to v. Here we understand that W: $u \longrightarrow v$ *is always a specific walk*, $W = e1e2 \dots ek$, although we sometimes do not care to mention the edges ei on it. The length of a walk W is denoted by $|W|$.

DEFINITION. Let $W = e1e2 \dots ek$ ($ei = uiui+1$) be a walk.

W is **closed**, if $u1 = uk+1$.

W is a **path**, if ui 6= uj for all i 6= j.

W is a **cycle**, if it is closed, and ui 6= uj for i 6= j except that $u1 = uk+1$.

W is a **trivial path**, if its length is 0. A trivial path has no edges.

For a walk W: $u = u1 \longrightarrow \dots \longrightarrow uk+1 = v$, also

$W-1$: $v = uk+1 \longrightarrow \dots \longrightarrow u1 = u$

Is a walk in G, called the **inverse walk** of W.

A vertex u is an **end** of a path P, if P starts or ends in u.

The **joint** of two walks $W1$: $u \longrightarrow v$ and $W2$: $v \longrightarrow w$ is the walk $W1W2 : u \longrightarrow w$.

(Here the end v must be common to the walks.)

Paths P and Q are **disjoint**, if they have no vertices in common, and they are **independent**, if they can share only their ends. Clearly, the inverse walk $P-1$ of a path P is a path (the **inverse path** of P). The joint of two paths need not be a path.

A (sub)graph, which is a path (cycle) of length $k - 1$ (k, resp.) having k vertices is denoted by Pk (Ck, resp.). If k is even (odd), we say that the path or cycle is **even** (**odd**). Clearly, all paths of length k are isomorphic. The same holds for cycles of fixed length.

Paths and cycles

DEFINITION. If there exists a walk (and hence a path) from u to v in G, let dG(u, v) = min{k | uk −→ v} be the distance between u and v. If there are no walks u −→ v, let dG(u, v) = ¥ by convention. A graph G is connected, if dG(u, v) < ¥ for all u, v ∈ G; otherwise, it is disconnected. The maximal connected subgraphs of G are its connected components.
Denote
c(G) = the number of connected components of G .
If c(G) = 1, then G is, of course, connected.
The maximality condition means that a sub graph H ⊆ G is a connected component if and only if H is connected and there are no edges leaving H, i.e., for every vertex
v /∈ H, the sub graph G[VH ∪ {v}] is disconnected. Apparently, every connected component is an induced sub graph, and
N.G (v) = {u | dG (v, u) < ¥}
is the connected component of G that contains v ∈ G. In particular, the connected components form a partition of G.

Shortest paths

DEFINITION. Let Ga be an edge weighted graph, that is, Ga is a graph G together with a weight function a: EG → R on its edges. For H ⊆ G, let a(H) = å ,e∈ H,a(e) be the (total) weight of H. In particular, if P = e1e2 . . . ek is a path, then its weight is a(P) = åki=1 a(ei). The minimum weighted distance between two vertices is d(a)
G (u, v) = min {a(P) | P: u −→ v} .
In extremer problems we seek for optimal sub graphs H ⊆ G satisfying specific conditions. In practice we encounter situations where G might represent
• A distribution or transportation network (say, for mail), where the weights on edges are distances, travel expenses, or rates of flow in the network;
• A system of channels in (tele) communication or computer architecture, where the weights present the rate of unreliability or frequency of action of the connections;
• A model of chemical bonds, where the weights measure molecular attraction.

Network Flows

DEFINITION. Let *f* be a flow in a network *N*. A path *P*: *s* −→ *r* is (f -) **improvable**, if *i*(*P*) > 0. On the right, the bold path has value *i*(*P*) = 1, and therefore this path is improvable. DEFINITION. Every network *N* has a **zero flow** defined by *f* (*e*) = 0 for all *e*. For a flow *f* and each subset *A* ⊆ *VN*, define the **resultant flow from** *A* and the **value** of *f* as the numbers val(*fA*) = *f* +(*A*) − *f* −(*A*) and val(*f*) = val(*fs*) (= *f* +(*s*) − *f* −(*s*)) . A flow *f* of a network *N* is a **maximum flow**, if there does not exist any flow *f ′* such that val(*f*) < val(*f ′*). The value val (*f*) of a flow is the overall number of goods that are (to be) transported through the network from the source to the sink.
Various transportation networks or water pipelines are conveniently represented by weighted directed graphs. These networks usually possess also some additional requirements. Goods are transported from specific places (warehouses) to final locations (marketing places) through a network of roads. In modeling a transportation network by a digraph, we must make sure that the

number of goods remains the same at each crossing of the roads. The problem setting for such networks was proposed by T.E. Harris in the 1950s. The connection to *Kirchhoff's Current Law* (1847) is immediate. According to this law, in every electrical network the amount of current flowing in a vertex equals the amount flowing out that vertex.

Flows

DEFINITION. A flow in a network N is a function f: $VN \times VN \rightarrow R+$ such that $0 \leq f(e) \leq a(e)$ for all e, and $f^-(v) = f^+(v)$ for all $v \notin \{s, r\}$.

DEFINITION. A **network** *N* consists of

- An **underlying digraph** $D = (V, E)$,
- Two distinct vertices *s* and *r*, called the **source** and the **sink** of *N*, and
- A **capacity function** a: $V \times V \rightarrow \mathbf{R}+$ (nonnegative real numbers), for which $a(e) = 0$, if $e \notin E$.

Denote $VN = V$ and $EN = E$.

Let $A \subseteq VN$ be a set of vertices, and $f : VN \times VN \rightarrow \mathbf{R}$ any function such that
$f(e) = 0$, if $e \notin N$. We adopt the following notations:
$[A, A] = \{e \in D \mid e = uv, u \in A, v \notin A\}$,
$f^+(A) =$ å
$e \in [A,A]$
$f(e)$ and $f^-(A) =$ å
$e \in [A,A]$
$f(e)$.
In particular,
$f^+(u) =$ å
$v \in N$
$f(uv)$ and $f^-(u) =$ å
$v \in N$
$f(vu)$.

Chapter 2

LITERATURE REVIEW

2.1). Arni Halldorsson et al. (2006)

Purpose – The author discusses and develops SCM as scientific disciplines using different theories from non-logistics areas to explain inter organizational phenomena. It also attempted to establish a frame of reference that allows us to mitigate the gap between the current SCM research and practice and the theoretical explanations of how to structure and manage supply chains.

Design/methodology/approach– The paper introduced three different perspectives that together will contribute to a broader understanding of SCM in practice: an economic perspective; a socio-economic perspective; and a strategic perspective. The theoretical framework was applied to two important research topics within SCM: third party logistics (TPL); and new product development (NPD).

Findings – There is no such thing as "a unified theory of SCM". Depending on the concrete situation, one can choose one theory as the dominant explanatory theory, and then complement it with one or several of the other theoretical perspectives.

Research limitations/implications – The way the four theories complement one another was explored on a conceptual basis, but further research into this direction may explore more deeply, how these alleged complementarities occur in practice, and how managers mould their decisions by these ideas.

Practical implications – The four theories can provide normative support to important management decisions in supply chains, such as outsourcing, safeguards against opportunism, and alignment of incentives..

2.2).V.M. Rao Tummala et al., Ali Reza Aliahmadi et al. and Seyed Gholamreza Jalali et al. (2006)

Purpose – The purpose of this study was to examine important operational issues related to strategic success factors that are necessary when implementing SCM plans in an organization.

Design/methodology/approach – A questionnaire was distributed to top and middle management within a large manufacturing firm, specializing in producing consumer and building products, to examine the importance and the extent to which the selected manufacturing company practiced the strategies based on these identified operational issues.

Findings – Reducing cost of operations, improving inventory, lead times and customer satisfaction, increasing flexibility and cross-functional communication, and remaining competitive appeared to be the most important objectives while implement SCM strategies. The responses by the survey respondents indicate that not enough resources were allocated to implement and support SCM initiatives in their divisions. In addition, they perceived that

resource allocation could be improved in the areas of better information systems, greater commitment, setting clear-cut goals, increased training, more personnel, and aligning SCM initiatives with current priorities and resource commitments.
Practical implications – The results would be helpful in providing greater understanding of strategic and operational issues that support SCM framework and implementing SCM strategies to reduce supply chain-wide costs and meeting customer service levels. The results may be useful for business managers to understand and implement SCM plans in terms of their importance and the company's culture.

2.3). Soo Wook Kim et al. and Nevena Yakova et al. (2006)

Purpose – The purpose of this research was to examine the causal linkages among supply chain management (SCM) practice, competition capability, the level of supply chain (SC) integration, and firm performance.
Design/methodology/approach – Causal linkages are helpful in developing a framework for linking a firm's SC integration strategy to its competitive strategy, and in identifying how such a linkage can be connected to the improvement of organizational performance. Such effort also should enable us to derive at a set of recommended strategies of SCM practices for SC integration.
Findings – From the results of LISREL analysis on small and large manufacturing firms, the authors reported that, in small firms, efficient SC integration may play a more critical role for sustainable performance improvement, while, in large firms, the close interrelationship between the level of SCM practices and competition capability may have more significant effect on performance improvement. It is concluded that, in early stage, the emphasis on systemic SC integration may be more crucial. Once SC integration has been implemented, it may be advisable to focus on SCM practice and competition capability.
Originality/value – It attempts to show how the potential benefits of integrating supply chain can no longer be ignored.

2.4). Drew Stapleton et al. (2007)

Purpose – The purpose of this article was to expand the base of supply chain knowledge by applying chaos theory principles to selected supply chain functions.
Design/methodology/approach –The author implemented chaos theory from the natural sciences, provide a basic explanation, and then examined how it may be applied to enhance supply chain management techniques.
Findings – Chaos theory principles were used to assist in the examination of forecasting, product design, and inventory management challenges currently facing supply chain practitioners.
Research limitations/implications – Application of chaos theory to various supply chain issues and key functional areas may produce an increase in the level of understanding of supply chain ambiguity and how chaos theory may provide valuable insight into the effective management of supply chain networks.
Practical implications – Author stated that, when applied correctly, chaos theory shows potential to be a tool that can be instrumental in helping explain why unpredictability occurs within nonlinear systems. A better understanding of this phenomenon may help researchers to develop better, more accurate models to assist managers in making better supply chain

management decisions, benefiting organizations and customers by simultaneously enhancing cost-effectiveness and improving customer service levels. The principles of chaos theory have been introduced as a method that shows early promise as a tool to enhance supply chain effectiveness.

2.5). Archie Lockamy III et al. (2007)

Purpose – The purpose of this paper was to examine the use of V-A-T analysis in the management of supply chain networks.
Design/methodology/approach – The paper provides a conceptual overview of V-A-T analysis as a procedure for categorizing manufacturing facilities, and explores the use of V-A-T analysis as a technique for the management of supply chain networks.
Findings – There are several challenges to the effective management of supply chain networks. However, organizations can overcome these challenges by understanding the nature of network control points as revealed through the application of V-A-T analysis on their supply chains.
Practical Implications –The concepts presented in this paper can be used by supply chain professionals to increase the likelihood of effective supply chain management within their organizations, and by supply chain researchers to further explore the use of V-A-T analysis as a tool for examining supply chain networks.
The paper makes a start in filling a void in the literature concerning how V-A-T analysis can be used as a tool to facilitate improved supply chain management.

2.6). Ding-zhong Feng et al. (2007)

A Novel Game-Theory-Based Analysis Approach for Running a Supply Chain
Purpose - As one of the most important management strategies, supply chain management (SCM) is increasingly being emphasized. And, an increasing focus is placed on the integration of overall supply chain resources. In running the strategy, one of key problems is how to judge the suitability that a project is managed by SCM paradigm. For this reason, a novel feasibility analysis approach based on game theory was presented in the paper for running a supply chain project.
Design/Methodology/Approach - First of all, some basic conditions for judging the feasibility of a SCM project are discussed both on individual rationality and group rationality. Then, a viable bargain price range of candidate partners was proposed by using Bayes-Nash equilibrium, and a numerical example is given to illustrate its application.
Findings - The relationship between the bargain price range and the competitive index in a SCM project was discussed. With the globalization of economic markets, the competitive relationship among enterprises increasingly becomes both competitive and cooperative thus the applications of game theory in SCM field attracted much attention of lots of researchers
Practical implications - Main works in this research domain could be summarized into three aspects. First, some researchers applied game theory to make decisions, such as whether to join a supply chain or not, and whether to share their information to other members in supply chain or not. Second, some research work was conducted on the coordination game process between enterprises. Third, profits allocation and risk control were paid a lot of attention. Some researchers proposed profits allocation model based on game theory, and discussed how to optimize allocation strategies.

2.7). Thomas Li-Ping Tang et al. and Ou Tang et al. (2008)

Purpose –This article aimed at examing the challenges of supply chain management and to propose a triple-C (cease-control-combine) remedy for the North American auto industry's supply chain management.

Design/methodology/approach – The authors applied management theories, collected information from managers at different levels of the auto industry's supply chain management, and developed a novel theoretical model of sustainability in supply chain management for the auto industry.

Findings – It was argued that outsourcing to low cost countries – the current supply chain strategy – is not only unsustainable but also irresponsible for the auto industry and society. A triple-C (cease-control-combine) remedy was proposed for the auto industry's supply chain management.

Practical implications – The proposed triple-C strategy will save the auto industry money in R&D investment, reduce quality cost and inventory waste, help the industry go through the volatile economy, and achieve sustainable development. With close relationships and strong supports from suppliers, the industry can speed up technology development, introduce new gas efficiency models quickly, and become less dependent on gas price. Finally, the triple-C strategy will help the industry keep jobs and generate new jobs in the USA. These activities lead to public support and restored corporate image. The current business environment was analyzed, problems of current supply chain strategy were discussed, and a new supply chain strategy remedy for the North American auto industry was proposed.

2.8). Vinod Kumar et al. and Jasbir Dhaliwal et al. (2008)

Purpose – The purpose of this research was to develop a conceptual framework for implementing and managing supply chain flexibility in supply chain organizations. The framework suggests that supply chain flexibility should be implemented and managed using a three-stage approach: required flexibility identification, implementation and shared responsibility, and feedback and control.

Design/methodology/approach – The major components of the proposed framework were based on a review of research in the manufacturing flexibility literature as well as the limited research in supply chain flexibility. The strengths and weaknesses of these frameworks, combined with a published empirical study were analyzed to identify the important issues that must be considered when implementing and managing supply chain flexibility, and those components that need to be incorporated into a new integrated framework.

Findings – This framework was constructed by synthesizing the strengths of other conceptual frameworks. As a result, the major components of the framework were supported by the current research on the implementation and management of manufacturing flexibility, as well as the current literature on supply chain management.

Research limitations/implications – Empirical research was needed to examine the nature and level of responsibility sharing among different supply chain partners as suggested in this framework. It was also important to empirically investigate what constitutes flexibility in the supply chain taxonomy in various industries. Another issue of managerial interest concerns the way different supply chain flexibility types relate to one another, and whether supply chain organizations should acquire certain supply chain flexibilities as a pre-requisite for developing

others. Further studies are necessary to further explain the contribution made by key enablers, such as information technology and communication, the internet, process technology, and training and labor skills, towards the acquisition of supply chain flexibility.
Practical implications – The implication of this new conceptual framework for managers is that it is easy to understand and is based on best practices in the research literature on manufacturing flexibility and supply chain management.
Originality/value – To researchers, this framework provides a springboard for conducting exploratory and confirmatory research on the process of implementing and managing supply chain flexibility.

2.9). B.S. Sahay et al. (2008)

Purpose – The paper aims to analyze research conducted for assessing the current state of supply chain management practices followed by Indian organizations and identifying important areas that need to be addressed in order to increase their competitiveness.
Design/methodology/approach – The paper started by proposing a framework for evaluating the supply chain strategy of an organization along the three key dimensions – supply chain objectives, supply chain processes, and management focus on supply chain activities. Data collected through survey questionnaire for the three dimensions has been used to assess the alignment of supply chain strategy with the overall business strategy through statistical analysis.
Findings – The research findings revealed that most of the Indian organizations have aligned their supply chain objectives with their business objectives. They are now on course of aligning their processes and management focus. Enhanced level of competitiveness would require Indian organizations to manage the three-dimensional alignment of achieving the agenda set by the business strategy.
Research limitations/implications – Further research work should be focused on: assessing the current level of supply chain processes; identifying critical supply chain focus areas for the business; and establishing specific performance measures for continuous measurement of supply chain efficiency improvement.
Practical implications – This paper provided a detailed study to help supply chain managers improve supply chain efficiency through alignment of supply chain objectives with business objectives, supply chain processes with management tools and supply chain focus areas with management focus. Improved supply chain efficiency will help Indian organizations maintain there competitiveness in a rapidly globalizing economy. The supply chain alignment model suggested in this paper provides a framework for realizing true supply chain efficiency and competitiveness. Different organizations will align their objectives, processes and management focus as per the focal areas of their organization depending on their capabilities and market situation. However, in every case Indian organizations need to act fast to capitalize on these opportunities to be competitive with the world market.

2.10). Chang Won Lee et al. and Teck-Yong Eng et al. (2008)

Purpose – The purpose of this paper was to present the relationship between supply chain linkages and supply chain performance (cost-containment and reliability of supply chain partners).
Design/methodology/approach – Multivariate regression models were developed in order to identify the characteristics of determinants of linkages in the supply chain stakeholders (suppliers, internal stakeholders and customers). The survey was administered to individuals identified from a list of US executive officers, directors, presidents, or vice presidents.
Findings – Internal integration is the most important contributor to cost-containment while integration with the supplier is the best strategy to achieve supply chain reliable performance. Availability of electronic ordering systems for customers is an important strategy in cost-containment. Fast and easy ordering is the best strategy for customer in performance reliability. Reliable delivery with supplier collaboration in managing a broad supply chain operation is the best way to link with suppliers. Access to the inventory information creates the most favorable environment in internal integration.
Research limitations/implications – A vigorous multivariate statistical modeling process was employed to seek a possible linkage between the level of integration and the supply chain performances at a different linkage stage. This study would open an avenue for further investigation using micro data such as financial performances, and other key supply chain indicators to operationalize some of the findings that this study presented.
Practical implications – This paper explored the relationship between supply chain linkages and supply chain performance so that management will be able to pursue better supply chain strategies applicable directly to their business environment. Study results provide management with innovative insights for planning and executing applicable supply chain strategies. This study also presented overall and individual determinants of each linkage affecting supply chain performance. In addition, this study presented a valid and reliable measurement instruments that academicians as well as practitioners can use in measuring the supply chain performance.

2.11). Mahesh S. Raisinghani et al. (2009)

Purpose –The purpose of this paper was to investigate the linkage between organization performance criteria and the dimensions of agility, e-supply-chain drivers and knowledge management.
Design/methodology/approach – The analytic network process was applied as the research methodology in the context of executive decisions that include qualitative and quantitative attributes. The decision model was presented, along with a case study with an e-supply chain of a global telecommunications company.
Findings – The study developed a framework for measuring the relative importance of a particular dimension based on the application of theoretical concepts from the information systems and management science literature to the digital, knowledge economy. Since contextual factors play a critical role in the design of effective knowledge-management (KM) systems, technical and process solutions need to be customized to fit the organization performance criteria, dimensions of agility and supply chain drivers.
Practical implications – The model presented is dependent on the perceptual weightings provided by the decision-maker and the generalizability of findings based on the model to other

organizations may be limited. This paper addresses the need for a strategic decision-making tool to assist management in determining which knowledge management construct is most beneficial in the development of an agile supply chain. It fulfils an identified information need and offers practical help in a dynamic and competitive environment by providing a decision model that assists in determining which construct of KM is most important based on an organization's performance criteria, dimensions of agility and supply-chain drivers.

2.12). Damien Power et al. and Jorge Verissimo Pereira et al. (2009)

Purpose – The purpose of this paper was to review a sample of the literature relating to the integration and implementation of supply chain management practices from a strategic viewpoint.
Design/methodology/approach – The literature wass examined from three perspectives. First, supply chain integration covers issues relating to integration of core processes across organizational boundaries through improved communication, partnerships, alliances and cooperation. Second, strategy and planning examines supply chain management as a strategic matter for trading partners, along with factors relating to the amount of planning required. Third, implementation issues concern factors critical for successful implementation, as well as issues specific to inter and intra organizational aspects of supply chain initiatives are contained in this sub-group
Findings – An important emergent theme from the literature was the importance of taking a holistic view, and the systemic nature of interactions between the participants. At the same time, it is also apparent that this requirement to take such a holistic and systemic view of the supply chain acts as an impediment to more extensive implementation. The strategic nature of adopting a supply chain wide perspective, on the one hand provides significant potential benefit, and on the other requires trading partners to think and act strategically. This is easier said than done within a stand-alone organization, let alone across a diverse and dispersed group of trading partners.
Practical implications – The scope of this review by design limited to a cross-section of the literature in this area. As such, it cannot, and does not, attempt to be an examination of the full range of the literature, but a sampling of important and influential works. This review of the literature serves to highlight the inter-dependence between integration (technologies, logistics, and partnerships), a strategic view of supply chain systems, and implementation approach. All three need to inform and underpin each other in order for management of supply chains to be able to deliver on the promise of benefits for all trading partners. This study reviewed a sample of recent and classic literature in this field and in doing so provides some clear guidelines for the conduct of future research.

2.13). Goran Svensson et al. and Martin Christopher et al. (2009)

Purpose – The purpose of this paper was to describe a conceptual framework of Supply Chain Management Ethics (SCM-ethics).
Design/methodology/approach – The research was based upon a qualitative approach using a series of semi-structured interviews. Multiple perspectives and respondent were applied in the data collection process. The study was limited to the Swedish vehicle industry.

Findings – The empirical findings indicated that the corporate focus of SCM-ethics is in part narrow in the Swedish vehicle industry. The partial focus may endanger the corporate ethical performance in the long run, while the immediate one may not be affected.
Practical implications – The approach undertaken and thereof empirical limitations restrict the generality of findings. However, a structure of operationalisation of SCM-ethics was introduced. It was based upon four orientations and nine areas of questions, all of which serve as a fundamental for further research. A practical implication the article explores the common grounds, and provides initial insights into the complex and multifaceted field, of SCM ethics.
It may be used for teaching, training and analytical purposes. It may also be used for further managerial exploration and replication of SCM ethics in business. The principal contributions were a conceptual framework based upon four distinctive orientations and a set of summarized interview series in the context of SCM-ethics, all of which may be of interest to both practitioners and scholars.

2.14).Michael Tracey et al. and Yu Chung and William Wang et al. (2009)

Purpose – The purpose of this article was to empirically test the impact of supply-chain management (SCM) capabilities on business performance so as to determine to what degree customer-oriented SCM issues influence competitive position and organizational performance.
Design/methodology/approach – A rigorous methodology was employed to generate a reliable and valid measurement instrument. Responses from 474 manufacturing managers were then utilized to test a causal model using LISREL[R].
Findings – The results indicated that significant positive relationships exist among three types of SCM capabilities (outside-in, inside-out, and spanning) and business performance (perceived customer value, customer loyalty, market performance, and financial performance).
Practical implications – The article demonstrates that strategically developing SCM capabilities such as efficient inbound and outbound transportation, warehousing, and inventory control, production support, packaging, purchasing, order processing, and information dissemination enable a manufacturing firm to identify and take advantage of opportunities in the global marketplace. The paper statistically validates that managers should regard the cultivation of SCM capabilities as a proprietary resource that facilitates competitive advantage. It also contributes a concise instrument that may be used by academics interested in the areas of supply-chain management processes and firm performance.

2.15). Taewon Suh et al. and Mats Abrahamsson et al. (2010)

Purpose – The primary purpose of this study was to examine the relationships between the level of trust and several relevant constructs drawn from transaction cost analysis (such as asset specificity, behavioral uncertainty, and partner's opportunism) and social exchange theory (informational sharing).
Design/methodology/approach – A comprehensive questionnaire based on various theories on trust and commitment was mailed in 2010 to supply chain practitioners in the Midwest region. A total of 171 valid returns were received out of 1,800 mailings (9.5 percent). A path analysis was used to estimate parameters or relationship between relevant constructs and trust, and trust with the level of commitment.

Findings – A firm's trust in their supply chain partner is highly associated with both parties' specific asset investments and social exchange theory. Information sharing has a primary impact on reducing a partner's uncertainty behavior which, in turn, would improve the level of trust. Finally, the level of commitment is strongly related to the level of trust.
Practical implications – This research used supply chain practitioners in one region as a target population. It is highly recommended to duplicate this study in other regions to verify the findings. This is the first research paper linking various variables to trust and trust to commitment in supply chain management using path model.

2.16). Erik Sandberg et al. (2010)

Purpose – Despite the often stated importance, little about top management's role in supply chain management (SCM) practices is known. The purpose of this paper was therefore to explore the role of top management in two retail companies that successfully utilize opportunities given by SCM practices.
Design/methodology/approach – As an empirical basis for the research, two Swedish retail companies were explored. Members of the top management teams have been interviewed about their role in the company and their priorities.
Findings – The top management role was described by introducing four archetypes; the supply chain thinker, the relationship manager, the controller and the organizer for the future. This paper added to the existing theory by giving a more detailed description of top management's role in SCM practices, i.e. how SCM practices could actually be managed, and, in the extension, to the understanding for what is needed to implement more SCM practices in real existing companies and supply chains.

2.17) Goran Svensson et al. (2011)

Purpose – The purpose of this paper was to provide insights and describe teleological approaches in the context of Supply Chain Management (SCM).
Design/methodology/approach – A conceptual framework was outlined derived from complexity sciences to widen and enhance the exploration and understanding of SCM.
Findings – Research and literature in the field of SCM have to a large extent neglected the possible underlying formative and rationalist nature of it, rather than considering or highlighting its potentially transformative nature.
Practical implications – Teleological approaches of SCM provided valuable insights in managing supply chains. They also provided innovative and challenging opportunities for further research in the field of SCM. The application of teleological approaches in supply chains may encourage and lead to managerial ideas and insights to anticipate and avoid deficient or erroneous grounds in the planning, implementation and evaluation of SCM. Teleological approaches make a contribution to the ongoing exploration and discussion of SCM, such as: incorporating a frame of reference from complexity sciences. The author believed that it also provides a timely topic in times of crisis as it compares different teleological approaches – some more dynamic and flexible than others.

2.18). Tobias Schoenherr et al. (2011)

Purpose – The purpose of this paper was to propose a comprehensive and coherent approach for managing risks in supply chains.
Design/methodology/approach – Building on Risk Management Process (RMP), this paper develops a structured and ready-to-use approach for managers to assess and manage risks in supply chains.
Findings – Supply chain risks can be managed more effectively when applying the Supply Chain Risk Management Process (SCRMP). The structured approach can be divided into the phases of risk identification, risk measurement and risk assessment; risk evaluation, and risk mitigation and contingency plans; and risk control and monitoring via data management systems. Specific techniques for conducting this process were suggested and implemented in industries.
Practical implications – While supply chain risk management is an emerging and important topic in our dynamic and interconnected world, conceptual frameworks providing a clear meaning and normative guidance are scarce. This paper presented such a framework, offering structure and decision support for managers.

2.19). Jan de Vries et al. and Robbert Huijsman et al. (2011)

Purpose – This paper seeks to be concentrated on the question whether any parallels can be found out between the industrial sector and health care services with respect to the developments that have taken place in the area of Supply Chain Management. It started from an analysis of existing literature, it was intended that different modes of Supply Chain integration would be discussed. Also, in doing so, it was intended that the lessons learned from the studies presented in this paper will be summarized and placed into the perspective of future research that can be considered as necessary.
Design/methodology/approach – This paper had adopted an exploratory, qualitative approach based on an analysis of existing literature in the area of Supply Chain Management in Health Services. Additionally, material from the case studies presented in this paper was used to assess the current body of knowledge regarding Supply Chain Management in Health Services.
Findings – Starting from a classification of existing research, five main research areas with respect to Supply Chain Management in a health care setting were defined. Additionally, it was concluded that next to studies with a mono-disciplinary focus, an interdisciplinary focus on Supply Chain Management issues in health services seems to be necessary.
Practical implications – This paper contributes to both the supply chain management literature and literature in the area of healthcare management by identifying some important research areas which are linked to both fields. This paper helps both academics and managers to gain a better understanding of the complexity of supply chain management in health services.

2.20). Per Hilletofth et al. (2011)

Purpose – The purpose of this paper was to form an understanding of how new product development (NPD) relates to supply chain management (SCM), why the two fields should be coordinated, and how this may be done.
Design/methodology/approach – This research used a literature review and case study research. The case study considers a Swedish company that operates on a global basis in the furniture industry. Empirical data have been collected mainly from in-depth interviews with key persons representing senior and middle management in the case company.
Findings – This paper stressed the need to produce innovative, value-adding products, as well as the necessity to quickly deliver them to the market. Companies that face mature business environments may encounter problems due to a high emphasis on either the value-creation processes, or on the value delivery processes. Therefore, NPD activities need to be coordinated with SCM activities on a strategic level, otherwise competitiveness will be lost.
Practical implications – The research was limited to one case company; replication studies would enhance understanding of the studied phenomenon. There is a wide need for research exploring how various parts of demand and supply chains should be managed in order to fully utilize the advantages of the consumer-oriented enterprise. This paper provides insights for researchers and practitioners on how to coordinate and balance NPD (demand side) with SCM (supply side) activities. It highlights that companies should organize themselves around understanding how consumer value is created and how these processes may be coordinated to provide that value. The two processes must be given equal attention and importance to avoid sub-optimization. The need for coordinating NPD and SCM activities has been emphasized in the literature but still remains relatively unexplored. This paper contributes by investigating this issue further

2.21). Herbert Kotzab et al. and Christoph Teller et al. (2011)

Purpose – The purpose of this paper was to develop a conceptual model that includes drivers of supply chain management (SCM) adoption and execution identified in the literature, provide a set of measurement scales that operationalise constructs within this model, empirically verify a hierarchical order of antecedents that affects the adoption and execution of SCM, and assist management by providing a focus on those SCM conditions and processes that need to be prioritized to increase successful SCM adoption and execution.
Design/methodology/approach – The conceptual model is tested empirically through a survey of 174 senior supply chain managers representing the biggest organizations within a central European country.
Findings – Using structural equation modeling the hypothesized hierarchical order of three proposed antecedents were verified: "internal SCM conditions" that affect "joint or external SCM conditions", which in turn influence collaborative "SCM-related processes". Firms that adopt these steps should enjoy a rigorous and appropriate road to the full execution of SCM.
Practical implications – The survey results reflect the views of large organizations in a country-specific supply chain setting.
The findings provide a hierarchical focus for financial, personnel and management initiatives to increase integration within a supply chain and improve competitiveness. The major contribution

of this paper was that it provides empirical proof of the antecedents that affect the adoption and execution of SCM.

2.23).Summary of the literature review of IT in SCM

S.No:-	Classification criteria	References
1.	Strategic planning for IT in SCM	Rockhart and Scott Morton (2006), Porter and Millar (2006), Gallupe et al. (2006),Henderson and Venkataraman (2006), Rogerson and Fidler (2006), Webster (2007),Sambasivarao and Deshmukh (2007), Fletcher and Wright (2007), Ho (2007), Maloni and Benton (2007), Williams (2007), Brown and Eisenhardt (2008), Cerpa and Verner (2008), Daniels (2008), King (2008), Bradley (2009), Teo and Ang (2009), Kardaras and Karakostas (2009), Ang et al. (2010), Zimmerman (2010), Christiaanse and Kumar(2010),Talluri(2010),Andersen(2011), van Hooft and Stegwee (2011)
2.	VE and SCM	Davidow and Malone (2006), Webster (2006), Mariotti (2006), Voss (2006), Skyrme(2007), Lewis and Talalayevsky (2007), Clements (2007), Clarke (2008), Kornelius and Wamelink (2008), Browne and Zhang (2009), Bal and Gundry (2009), Naylor et al.(2009),Black and Edwards (2010), Boardman and Clegg (2010), Bhatt and Emdad(2010), van Hoek (2010), Sarkis and Sundararaj (2011), Turowski (2011)
3.	E-commerce and SCM	Emmelhainz (2006), Cooper (2006), Chiu (2006), Carbone (2006), Bowersox and Daugherty (2006), Benjamin and Wigand (2007), Kalakota and Whinston (2007),Murray (2007), Christopher (2007), Roberts and Mackay (2007), Frook (2007), Feraud (2008), Min and Galle (2008), Walton and Gupta (2008), Ball and Wright (2008),Reynolds (2009), Doherty (2009), Elliman and Orange(2009),Emiliani(2009),

		Fontanella (2009), Hackney et al. (2009), Kaplan and Sawhney (2009), Lancioni et al. (2010), Marshall and McKay (2010), McIvor et al. (2010), Overby and Min (2010),Wang (2010), Salcedo and Grackin (2010), Croom (2010), Damen (2001), Emiliani and Stec (2010), Kehoe and Boughton (2010), Murillo (2010), Overby and Min (2011), van Hoek and Chong (2011), Alshawi (2011)
4.	Infrastructure for IT in SCM	Klouwenberg et al. (2006), Mason-Jones and Towill (2006), Mukherji and Mukherji (2007), Walsh and Koumpis (2007), Watson et al. (2007), Haeckel (2007), Ranchhod and Gurau (2008), Al-Mashari and Zairi (2008), Attaran (2008), Huang and Mak(2008), Jayaram et al. (2009), Lau and Lee (2009), Perry and Sohal (2009), Cheng et al. (2010), Humphreys et al. (2010), Au and Ho (2010), Sarkis and Sundararaj (2010),Sharma and Gupta (2011), Yamaya et al. (2011)
5.	Knowledge and IT Management in SCM	McCampbell et al. (2006), Angeles and Nath (2006), Motwani et al. (2007), Talluri (2007), Walsh et al. (2008), Boubekri (2008), Nah et al. (2009), Tracey and Smith-Doerflein (2009), van Hoek (2010), Warkentin et al. (2010), Jutla et al. (2010), Spekmanet al. (2010)
6.	Implementation of IT in SCM	Cooper and Zmud (2006), Ho (2006), Scott (2007), Hicks (2007), Mullin (2008), Calza and Passaro (2008), Williams et al. (2008), Williford and Chang (2009), Angeles and Nath (2009), Lauer (2010), Al-Mashari and Zairi (2010), McIvor et al. (2010), Pawar and Driva (2011), Kuruppuarachchi et al. (2011)

2.24).Summary of the frameworks used for developing supply chain flexibility framework

S.No:	Author(Year)	Framework(Objectives)
1.	Swamidass and Newell (2006)	Manufacturing flexibility as an effective strategy to address uncertainty. The framework highlights the relationship between manufacturing flexibility and business performance
2.	Kumar and Kumar(2006)	Identifies four sources of uncertainty (environmental uncertainty, input, output, and processes). This framework highlights that each type of uncertainty in its turn requires a different and particular type of flexibility to accommodate it
3.	Sethi and Sethi (2007)	Identified 11 manufacturing flexibility types, classifying them in three levels: component (or basic), system, and aggregate. The framework highlights that information technology and organizational structure are essential enablers to achieve the identified flexibility types
4.	Suarez et al. (2007)	Framework identified internal and external flexibility source factors. Fit between the required and observed types and levels of flexibility when implementing and managing manufacturing flexibility improves organizations' performance. The framework emphasized the importance of non-technical means in achieving manufacturing flexibility
5.	Hyun and Han (2007)	Framework classified various types of flexibility from three viewpoints: systems, environmental-associated, and decision-hierarchical and highlighted that manufacturing flexibility exists at different levels
6.	Gerwin (2008)	Framework examined five variables: specifically identifying environmental uncertainties, developing a manufacturing strategy, determining the required manufacturing flexibility, implementing the required flexibility, and developing performance measurements. Outlined the relationship between actual, potential, and requires flexibility. Framework identified four generic strategies: adaptation, reduction, banking, and reduction
7.	Vickery et al. (2008)	This empirical study examined the dimensions of supply chain flexibility and their relationships with the environmental uncertainty, business performance, and functional interfaces
8.	Vokurka and O'Leary-Kelly (2009)	This framework identified four exogenous variables that are believed to influence the firm's choice of manufacturing flexibility types, which will in turn influence business performance. These variables are organizational strategy, environmental factors, organizational attributes, and technology
9.	Narain et al. (2009)	This framework outlined the link between manufacturing, marketing, and organizational strategies. Highlights that manufacturing flexibility exists at different levels

10.	Zhang et al. (2010)	This model applied competence and capability theory to value chain flexibility, and it explored the relationships among environmental uncertainty, value chain flexibility, and competitive advantage
11.	Correa (2010)	Outlined relationship between planned and unplanned changes and manufacturing flexibility
12.	Beach et al. (2011)	Highlights relationship between business strategy, environmental uncertainty and manufacturing flexibility. Suggested that organization must continually measure performance and monitor required flexibility to ensure that it is still required as a result of changing environmental uncertainty and strategy

2.25).Thematic summary of the literature review of SCM

S.No:-	Category	Authors and Main Findings
1.	Communication and partnership activities	Tan et al. (2006) Effective customer relations positively affects performance Romano and Vinelli(2006) Joint definitions and co-management of goals by partner organizations(customers/suppliers) improve supply networks ability to meet the expectations of the final consumer Waterson et al.(2006) Survey revealed that supply chain partnering predicted for future use by more than 60% of companies Romano (2007) ISO 9000 certified suppliers tend to be more reliant and viewed by customers as more trustworthy Wong and Fung(2007) Collaborative and structured relationships with suppliers in meeting quality objectives (case study) Mangiameli and Roethlein (2007) Multi-directional communication between channel partners (case study) Stanley and Wisner(2008) Implementation of cooperative purchasing/supplier relationships had a significant association with purchasing ability to deliver service quality to internal customers Forza and Filippini(2008) Obtaining customer satisfaction (caused construct) requires greater attention to factors which concern downstream relations with customers such as the involvement in quality improvement programs (causing construct=TQM link with customers) Wong (2009) Application of the supply chain excellence model applying TQM principles (7themes) that provides

		insight into success factors of managing supply partners Mehra et al. (2009) Study of future role of TQM in businesses facing global markets. Literature review was grouped into 5 categories include ‘‘supplier support’’ and ‘‘customer orientation’’ (customer focus) Choi and Hartley(2010) Supplier selection practices suggested that quality conformance is most important factor Fynes and Voss (2010) Strong buyer-supplier relationships will improve design quality.
2.	Process integration and management	Romano and Vinelli(2006) Defined and developed new product/process solutions at both the operative and strategic level in order to meet final consumer requirements (case study) Salvador et al.(2006) Interacting with customers on both quality and materials flow issues generally affect an organization's time-related performance as partially mediated by changes to/improvements to internal practices Gotzamani and Tsiotras (2007) Use of ISO 9001 offers good first step towards TQM (standard includes process management) Work practices tied to close interactions with customers and suppliers ISO 9001's most important contribution is process management Segars et al. (2007) Formalization of process boundaries extending to suppliers and customers (Value-added processing) Beamon and Ware(2008) System process quality model for identification, measurement and control of supply chain system Singer et al. (2008) Cost model analyzing how vertical integration improves quality for the end customer while increasing cost (mutually beneficial transfer contract) Mehra et al. (2009) Study of future role of TQM in businesses facing global markets. Literature review grouped into 5 categories of management concentration including customer focus, process focus, innovation focus and environmental focus Park et al. (2009) Process management found to be a practice employed by ‘‘high performers’’ thus having effect on quality, delivery, cost performance (as evaluated by customer). Processes include statistical techniques, cycle time reduction, continuous improvement Ahire and Dreyfus(2010) Process quality management (involvement of

		customers/suppliers in process design) has a positive effect on external quality (enables final quality)
3.	Management and leadership	Tan et al. (2006) Management responsiveness to firm's competitive environment, involvement and effectiveness and management understanding of and use of TQM tools, management of supply base and customer-focus positively affects performance Yeung et al. (2007) Quality management (ISO 9001, customer focus, supplier management) effectiveness is dependent on the attitudes and commitment (also confidence of understanding the requirements) of senior management Mehra et al. (2009) Study of future role of TQM in businesses facing global markets. Literature review grouped into 5 categories of management concentration including customer focus (customer partnership), process focus, innovation focus (knowledge-creating leadership) and environmental focus
4.	Strategy	Tan et al. (2006) Effective management of supply base activities and customer-focus positively affects performance (use of TQM tools and practices, link business practices to performance, alignment of business practices to strategy) Narasimhan and Jayaram (2006) Causal framework that suggests that supplier integration, strategic integration and customer integration across the supply chain determines customer responsiveness Ulusoy (2007) Strategies supporting quality is fundamental requirement for sustaining existence in market (survey of Turkish firms) Tan et al. (2007) Linking of business practices to performance. Factors studied SC integration, info sharing, SC characteristics, customer service management, JIT, geographical proximity. Integration requires massive commitment from all supply chain members Olhager and Selldin (2007) Survey of supply chain strategies including supply chain (SC) design, SC integration, SC planning and control and SC communication (e.g. supplier selection based on quality most important) Kanji and Wong(2008) Development of SCM model. Principles and concepts include leadership, customer focus, cooperative relationship, integrated process and information management, continuous

		improvement and business excellence Mangiameli and Roethlein, (2008) Multi-directional quality awareness and communication between channel partners (case study) can be a competitive advantage Tan et al. (2008) Firm's internal quality approach and supply base management practices can play a significant role in achieving corporate objectives if implemented concurrently Rosenzweig et al.(2009) Integration intensity and positive performance effects (quality, delivery, reliability, flexibility, cost leadership) of highly integrated supply chains Shin et al. (2009) Supplier management orientation positively associated with business performance (both buyers and suppliers) Ulusoy (2009) Best practices from benchmarking survey and supply chain analysis are logistics, supplier relations, customer relations and production Tan et al. (2009) SCM factors JIT capability and supply chain characteristics have positive relationship with overall product quality Delivery and communications improve overall customer service levels Six constructs of SCM practices Forker et al. (2009) Practices positively related to performance: (1) Supplier QM, (2) Role of the Q. Dept., (3) Training, (4) Q. Data and reporting. Product/ service design varied among firms Waterson et al.(2010) Most successful practices for quality improvement: TQM, Team-based groups, Manufacturing Cells and Integrated computer-based technologies (survey). Most common practices: SC partnering, TQM, JIT, team-based working and integrated computer-based technology (survey) Romano et al. (2010) ISO 9001 certified suppliers are characterized by better level of quality system, greater top-management involvement in formulating, supporting and communicating quality strategy, and larger diffusion and use of quality management procedures (e.g. more advanced internal quality system) Choi and Rungtusanatham (2010) Comparison of TQM practices at different levels of the

		supply chain Anderson et al.(2010) Investigates firms' motivation for ISO 9001 adoption such as improved product quality, internal improvements, communication value to external parties (public signal of credible quality attainment) Johnson (2010) QS-9000 adoption in the supply-base to evaluate organizational variables and performance outcome results (quality ppm, delivery performance) to 1st tier customers Terziovski et al.(2010) ISO 9001 certification and positive impact on performance. Individual element found to provide largest contribution is customer focus. Principle motivation found to be customer pressure Yeung et al. (2011) ISO 9000 as an operational-based program serves as foundation for continuous improvement (extension to supplier management, customer focus and satisfaction, process control) Khouja (2011) Two-stage supply chain inventory model investigating quality output and JIT production

2.26) Summary of frameworks/models/approaches used for evaluating, designing, integrating, analyzing, optimizing SCM

S.No.	Author(Year)	Framework/Model/Approaches
1.	Mark.fox et.al.(2006)	Agent oriented SCM
2.	Federico Caniato (2006)	Exploratory factor analysis and hierarchical regression
3.	S.G.Deshmukh (2006)	Coordinated -procurement model
4.	HP Wiendahl HP(2006)	Automatic production control applying control theory
5.	RW Grubbstrom (2006)	MRP theory
6.	A.Bensoussan(2006)	QVI approach
7.	Arshinder (2006)	AHP-fuzzy model
8.	Premaratne.Samaranayake (2006)	Framework and planning approach
9.	Arshinder (2007)	Analytical model
10.	Haralambos Sarimveis (2007)	Approximate dynamic programming,

	(review paper)	
11.	Haralambos Sarimveis (2007) (review paper)	Robust control
12.	Haralambos Sarimveis (2007) (review paper)	Model predictive control,
13.	Haralambos Sarimveis (2007) (review paper)	Optimal control model
14.	Arshinder (2007)	Co-ordination theory
15.	Haralambos Sarimveis (2007) (review paper)	Dynamic programming, Classical control theory
16.	Jean-Claude Hennet (2007)	
17.	Bongsug (Kevin) Chae (2007)	Game theoretic approach
18.	R.Cigolini (2007)	Six-sigma based methodology
19.	Giovani J.C. da Silveria (2007)	Three way fold approach and new normative tool developed
20.	Arshinder (2007)	Regression analysis
21.	Arshinder (2007)	SAP-LAP MODEL
22.	Gioconda Quesada (2008)	Holistic approach
23.	Stephan Vachon (2008)	International survey and ANOVA for statistical analysis
24.	Jagjit Singh Srai (2008)	Linear regression analysis
25.	Goran Svensson (2008)	Mapping approach
26.	Anna Nagurney (2009)	Qualitative approach using a series of semi-structure interviews.
27.	Rajesh Rajaguru (2009)	Nash-Cournot equilibrium (contribution to game theoretic approach in an oligopolistic setting)
28	Enver Yucesan (2009)	Causal research approach and survey methodology
29.	Kim Sundtoft Hald (2010)	Fuzzy newsvendor approach
30.	S.Afshin Mansouri (2010)	Multiple, longitudinal case research methodology
31.	Shabnam Rezapur (2010)	Multiobjective optimization
32.	Anna Nagurney (2010)	Equilibrium model with modified projection method
33.	Behrooz Karimi (2011)	System optimization
34.	Krishna R. Reddi (2011)	Bi-level programming approach
35.	Yufeg Zhang (2011)	System dynamics modeling
36.	Dominique Estampe (2011)	Theory building approach based on case studies
37.	Balan Sundarakani (2011)	Evaluation models
38.	Balan sundarakani (2011)	Lagrangian box model , Eulerian box model
39	Krishnendu Shaw(2011)	Fuzzy AHP and multi objective linear programming

2.27) Review of effect of ICT on SCM management and performance

2.27.1) ICT-SC performance

The majority of the papers showed that ICT at least has some effect on SC performance. Five papers do not support the positive effect: Jeffers et al. (2008), Li et al. (2008), Tan et al. (2010), Vickery et al. (2010), and Ward and Zhou (2006). Additionally, Sanders and Premus (2002) find that ICT usage directly influences operational performance, but does not influence strategic performance.

2.27.2) ICT-SC performance via SCM

All papers listed in this group found a positive influence from ICT via SCM to SC performance, but different models and approaches were followed. A first remark is that some papers (such as Frohlich and Westbrook, 2002; Rai et al., 2006; Sanders, 2007) do not differentiate explicitly between SCM and ICT. They incorporate explicit ICT elements in their SCM variables and assess the joint effect of SCM and ICT as one factor instead of two separate factors. We have chosen to classify these papers as mediating. A second remark is that several papers (Sanders and Premus, 2005; Sanders, 2007; Iyer et al., 2009) combine some of the basic models into their research model. They investigate both a direct effect of ICT and a mediating effect of SCM on SC performance. As a consequence, they are listed in both groups. Only three papers (Kim and Narasimhan, 2002; Jeffers et al., 2008; Vickery et al., 2010) explicitly investigate the moderating effect of SCM on the ICT-performance relationship.

2.27.3) ICT-SCM

The final group in Table 2.1 lists the papers that investigate a relationship between ICT and SCM. Within this group some papers exclusively search for the relationship between ICT and SCM (Cagliano et al., 2003, 2006) while others investigate this relationship in the context of the ICT-SC relationship via SCM (Paulraj and Chen, 2007). Again, most papers found a relationship. Only three papers did not found a relationship: Cagliano et al. (2006), Devaraj et al. (2007), and Zhang and Dhaliwal (2009). That is partly a surprise, as we intended it to be a means to classify rather than to represent research or reality. First, it is remarkable that almost all research so far has only investigated direct and mediated relationships, while ignoring mostly the joint or complementary effect of ICT and SCM. With respect to this joint effect we only found Kim and Narasimhan (2002), Jeffers et al. (2008), and Vickery et al. (2010) in our search. Second, to some extent the empirical findings are less confusing and contradicting than we originally expected. However, as indicated, many different variables and measurements have employed representing the key variables ICT, SCM, and SC performance. Surprisingly, our review seems to indicate that a positive effect on performance can be expected, irrespective of what type of ICT and aspect of SCM is used and irrespective of the performance measure considered.

First, two recent papers (Tan et al., 2010; Vickery et al., 2010) do not find a direct effect of EDI. However, Tan et al. (2010) find a mediating effect, while Vickery et al. (2010) show a moderating effect of EDI. Further, it seems that implementing ERP/MRPII is not always having a direct, positive effect on performance. We submit that nowadays, such systems have become a standard, which will not result in direct performance improvements. Evidence can be found in Table 2.1 that shows that four of the eight non-confirming papers (Cagliano et al., 2006; Jeffers et al. (2008); Li et al., 2008; Ward and Zhou, 2006) incorporate ERP/MRPII in their measurement of ICT. Two other papers that incorporate ERP/MRPII (Jayaram et al., 2000; Sanders and Premus, 2002) do find positive effects, but these are relatively early published papers. Still, performance improvements by means of ERP/MRPII can be reached if it becomes an organizational capability as the findings of Rai et al. (2006) suggest or in case its acts as a moderator of SCM practices, as the findings of Jeffers et al. (2008) show. More general, it suggests that ERP/MRPII will be beneficial if it really gets intertwined into organizational practices. Another explanation for the limited effect of the usage of ERP/MRPII might be the internal focus of it, which does not directly relate to the cross-organizational nature of SCM and SC performance. Finally, all eight non-confirming papers do not incorporate contextual factors. Therefore, it is impossible to find out if the non-confirmation of the effect of ERP/MRPII or EDI can be attributed to different effects in different contexts. Welker et al. (2008) find in their study that a positive effect of ERP systems is more likely in a more stable business environment. Second, it seems that more aggregated or general measures of ICT can be associated with positive results as is confirmed by all studies with that use such measures, except Zhang and Dhaliwaj (2009). That finding might indicate that in general ICT has benefits, but not all aspects or types have a positive effect. In fact, our findings and discussion of measurements and relationships suggests that we do not yet fully understand which types, aspects and dimensions of ICT, SCM, and performance influence each other and what the underlying mechanisms are.

Third, we think that another explanation for the mixed results can be found in how the relationship between ICT and SCM develops. Rather than believing that the pure presence of ICT will be beneficial, we need to distinguish different stages in the employment of ICT: ICT investment, ICT usage and ICT capability. The RBV of the firm offers a useful framework to relate the SC performance of organizations to resources and capabilities in the three stages of ICT employment. In the first stage of ICT employment, ICT investment, companies adapt themselves to ICT. However, the ICT employment is very limited and/or the companies invest only in standard ICT. According to the RBV such investments do not provide any sustainable advantage or performance gains as they can easily be imitated by competitors (Wooldridge and Floyd, 1990; Powell and Dent-Micallef, 1997; Zahra and Covin, 1993). As a consequence, the expected benefits of ICT will be limited, and can even be negative as shown by Vlosky (1994) and Vlosky and Wilson (1994), who found short-term disruptions in stable buyer-supplier relationships due to new technology adoption. In the second phase of ICT employment: ICT usage, the impact of ICT on SCM and some aspects of SC performance might become measurable. Nevertheless, in this stage, ICT is still not a company capability and the ICT usage can easily be mimicked by competitors. A competitive advantage cannot be expected, even if the operational performance is increased (Sanders and Premus, 2002). In the third stage of ICT capability, a firm leverages its investments to create unique ICT resources and capabilities that determine a firms overall effectiveness (Clemons 1986, 1991; Clemons and Row, 1991; Mata et al., 1995). Now, a sustainable advantage might be reached. ICT capability represents a competence that is not easily mimicked, as it is established through a combination of ICT and other resources of a firm. This explanation is confirmed in the literature, that as the paper measures ICT investment (Ward and Zhou, 2006), does not find a relationship with performance, while the papers using ICT capability measures direct or indirectly confirm a relationship between ICT and performance. Finally, papers that use a measure related to ICT usage show inconsistent results, also in line with the RBV. An explanation might be that this stage is between ICT investment and ICT capability. Positive results indicate that already some benefits of the next stage might have been captured, while no effects show that a firm is still very close to the investment stage.

Intra-organizational Technologies

Paper	**Stage**	**ADCS,TEDS**	**Electronic-boards**	**APS**	**SFM**	**ERP,MRP-II**
Bayraktar et al.(2009)	U	X		X		X
Cagliano et al. (2003)	U					
Cagliano et al. (2006)	U					X
Da Silveira and Cagliano (2006)	U/C					
Devaraj et al. (2007)	U/C			X		
Dong et al. (2009)	I/U					
Frohlich and Westbrook (2002)	I		@			
Hafeez et al. (2010)	U					
Heim and Peng (2010)	U					
Hill and Scudder	U					X

(2002)						
Hsu et al. (2008)	U					
Iyer et al. (2009)	U					
Jayaram et al. (2000)	U	X		X	X	X
Jeffers et al. (2008)	U	X		X		X
Kent and Menzter (2003)	U/C	X				
Kim and Narasimhan (2002)	U		@			
Lai et al. (2008)	U					
Li et al. (2009)	U	X				X
Narasimhan and Kim (2001)	U		@			
Olson and Boyer (2003)	C					
Paulraj and Chen (2007)	U	X				
Paulraj et al. (2008)	U	X				
Power and Singh (2007)	U		@			
Rai et al. (2006)	C	X		X		X
Rosenzwig (2009)	U					
Saeed et al. (2005)	U					
Sanders (2007)	U/C					
Sanders (2008)	U					
Sanders and Premus (2002)	U	X	X			X

Sandrus and Premus (2005)	C		@			
So and Sun (2010)	U					X
Subramani (2004)	U		@			
Swafford et al. (2008)	U		@ (except APS/ERP)			
Tai et al. (2010)	U					
Tan et al. (2010)	C					
Wong et al. (2009)	U		@			
Vickery et al. (2003)	U				X	
Vickery et al. (2010)	U				X	
Ward and Zhou (2006)	I			X	X	X
Zhang and Dhaliwal (2009)	U/C		@			

Notes: - I - investment; U-usage; C- capability; ADCS –automatic data capture system; SFM- system for manufacture (including CAA/CAM and CIM); TEDS –training and/or expedite delivery system

Inter-organizational Technologies

Paper	Stage	Internet, Web-enabled	Extranet	E-business	E-mail, Fax	EDI	XML
Bayraktar et al.(2009)	U			X		X	
Cagliano et al. (2003)	U	X					
Cagliano et al. (2006)	U		@				
Da Silveira and Cagliano (2006)	U/C	X	X	X		X	

Devaraj et al. (2007)	U/C	X				X	
Dong et al. (2009)	I/U	X		X			
Frohlich and Westbrook (2002)	I	X					
Hafeez et al. (2010)	U		@				
Heim and Peng (2010)	U	X	#				
Hill and Scudder (2002)	U					X	
Hsu et al. (2008)	U					X	
Iyer et al. (2009)	U	X		X		X	
Jayaram et al. (2000)	U					X	
Jeffers et al. (2008)	U					X	
Kent and Menzter (2003)	U/C					X	
Kim and Narasimhan (2002)	U					X	
Lai et al. (2008)	U					X	
Li et al. (2009)	U					X	
Narasimhan and Kim (2001)	U		@				
Olson and Boyer (2003)	C	X					
Paulraj and Chen (2007)	U	X	X		X	X	
Paulraj et al. (2008)	U	X	X		X	X	
Power and Singh (2007)	U			X			X
Rai et al. (2006)	C		@				
Rosenzwig (2009)	U			X			
Saeed et al. (2005)	U	X	X			X	

Sanders (2007)	U/C			X			
Sanders (2008)	U		@				
Sanders and Premus (2002)	U	X					
Sandrus and Premus (2005)	C		@				
So and Sun (2010)	U		X			X	
Subramani (2004)	U		@				
Swafford et al. (2008)	U		@				
Tai et al. (2010)	U	X		X			
Tan et al. (2010)	C					X	
Wong et al. (2009)	U		@				
Vickery et al. (2003)	U					X	
Vickery et al. (2010)	U		@			X	
Ward and Zhou (2006)	I		@				
Zhang and Dhaliwal (2009)	U/C		@				

Table (2.1) :- Review table of ICT

Notes: - I-investment; U-usage ; C-capability; @- ICT measured in aggregated terms;#-supported by software

2.28) Review of supply chain performance measurement

1) Papers that focus on 'general trends and issues in supply chain'

Meixell and Gargeya (2005) provided a comprehensive, critical review and classification of global supply chain literature and put forward the emerging trends in historical perspective. Outsourcing, vendor managed inventory (VMI), integration across tiers, internal and external integration, and the need of various performance measurement criteria are emphasized as the main trends. A matching between product life cycle and types of supply chain, including agility and lean supply chain classifications, is suggested by Vonderembrese et al. (2006). Detailed descriptions of lean and agile supply chain are provided and their work is supported with three case studies: Black & Decker, IBM and Daimler Chrysler. Swafford et al. (2008) investigate the relationship among IT integration, SC flexibility, SC agility and business performance through a US case-based study. Their study reveals the 'domino effect' among IT integration, SC flexibility, SC agility and competitive business performance. These papers clearly reveal the main trends and the importance of the IT integration, flexibility, agility and lean concepts for today's supply chain management.

2) Papers using 'dynamic modeling' approach

Puigyaner and Lainez (2008) use multi-stage, multi-period, stochastic mixed integer linear model combined with control theory to optimize corporate value. They develop a strategic level model using forecasting, optimization and simulation in tandem, and analyze the results using sample scenarios. Their comprehensive model involves demand and price uncertainty and financials (assets, liabilities, credit policies, capacity expansion, shareholder value, etc). Perea et al. (2008) use dynamic modeling approach combined with classical control theory to develop a generic dynamic framework for supply chain modeling.

These two papers emphasize the importance of capturing supply chain dynamics at various decision levels and they provide clear indications that modeling efforts to handle these dynamics are still continuing in literature.

3) Papers having direct focus on 'supply chain performance management'

Papers categorized in this group deal with various aspects of performance measurement system, including metrics classifications, problems of the current performance measurement systems and the need for the establishment of a new performance measurement. Gunasekaran et al. (2004) develop a framework for supply chain performance measurement. The article provides a detailed 'measurement and metrics classification' and uses a survey aiming at assessing importance within each metric group. Three main classes of performance measures are discussed by Martin and Patterson (2009): inventory, cycle time and financials. Effects of supply relations (organizational structure, partnering, supplier agreements and process improvements) on the performance measures selected are investigated via a survey-based study.

Gunasekaran and Kobu (2007) offer a comprehensive review and classification for supply chain measurement and metrics. A trend of increasing attention on performance measurement and metrics, both in practice and literature, is emphasized in their work.

This idea is also supported by McCormack et al. (2008). Gunasekaran and Kobu (2007) highlight the confusion as to the classification of metrics in literature, and lacking complete coverage of all the performance measures. Their review classifies the literature based on the following criteria: balanced scorecard perspective, components of measures, location of measures, decision levels, nature of measures, measurement base, traditional versus modern measures. They treat a number of metrics in five classes: order planning, supplier evaluation, production level, delivery and customer and they conduct an empirical research to assign importance ratings within each class. The work is a clear support for the need of new metrics for the new organization.

A comprehensive discussion of pressures and approaches for the new organization appears in Gunasekaran et al. (2005). The study is also the direct justification for the need of a new performance measurement and costing system. Supporting the idea of new performance measurement system, Yao and Liu (2006) and Ho (2007) propose different approaches. Yao and Liu (2006) suggest an integrated approach for measuring supply chain performance, combining economic value added (EVA), the balanced scorecard (BSC) and activity based costing (ABC), clearly emphasizing the need of overhead handling and a balanced approach. Ho (2007) focuses on ERP-based supply chain performance and proposes an integrated method, total related cost measurement, to evaluate supply chain performance of a three-echelon, ERP-based supply chain system. The study uses simulation-based validation experiments. Bernardes and Zsidisin (2008) investigate the relation of strategic supply chain management with the concepts of network embeddedness and network scanning, specifically focusing on the concept of embeddedness and network scanning in relation to performance. Their work involves a survey-based study made in US manufacturing, supported by rigorous statistical analysis. Papers under this subsection point to problems of the current performance measurement system and provide clear evidence that literature is still in need of a new supply chain performance measurement system which can handle the requirements of the new supply chain era.

4) Papers investigating the process maturity–supply chain performance relation

Three papers by McCormack focus on process maturity concept and investigate the relation with respect to supply chain performance. Lockamy and McCormack (2004) investigate the relationship between supply chain management planning practices and supply chain performance based on four main decision areas of SCOR model (plan, source, make, deliver) and result in the importance of planning function and the importance of collaboration, process measures, process collaboration, process credibility, process integration and information technology. McCormack and Lockamy (2004) develop a process maturity model taking the business orientation view, defining five general levels of process maturity and using the survey instrument to analyze the relationship of process maturity with performance. McCormack et al. (2008) take the supply chain operations reference (SCOR) model and business process orientation maturity model of McCormack and Lockamy (2004) as a base. The study provides a comparison on the traditional versus innovative performance measurement systems. A Brazilian survey is conducted in the study for clustering performance of the companies surveyed. The study puts forward a clear support for the need of new performance measurement methodologies and maturity models, emphasizing the importance of survey-based studies. These three papers highlight the maturity and performance relationship and provide clear evidence that literature is still in search of maturity models and roadmaps, which are proven to have direct correlation with performance.

5) Papers focusing on modeling, prioritization and dependence modeling of KPIs

Papers classified in this group aim at dealing with hierarchical nature, dependency and complexities of KPIs and suggest various approaches to handle these complexities. Bhagwat and Sharma (2007) provide a comprehensive review on BSC and AHP, focusing on prioritization and choice of metrics and measures. They propose an AHP approach based on a Western-India survey. The challenge, intricacy, dependency and conflicts of supply chain performance measurement system are emphasized by Cai et al. (2008). They utilize an iterative, analytical approach based on Eigen values and suggest a model to handle KPI dependencies, considering the cost of improving KPIs at each iteration. Hwang et al. (2008) performed a case-based study for the Taiwanese TFT-LCD (thin film transistor-liquid crystal display) manufacturing sector. Their work contains a comprehensive SCOR overview and stepwise regression analysis to analyze the dependency of different performance measures. They specifically focus on the 'sourcing' side of the SCOR model. It is evident that modeling the hierarchical nature and dependencies among various KPI's is still an unresolved and challenging issue in supply chain domain.

6) Papers focusing on the 'human/organizational' sides of the performance management

Papers falling in this class deal with the concepts of 'enabling performance management', 'total supply chain quality' and the concept of 'fit' in relation to performance measurement. Kanji and Wong (1999) point out the 'human side' of the issue is not covered in most of the work on SCM. The concept of total quality management (TQM) is extended to supply chain and the need for 'business excellence indices' is highlighted. In today's understanding of supply chain excellence, collaboration, agility and flexibility are among the critical success criteria and today's supply chain performance management still appears to be having difficulty in measuring the degree of collaboration, agility and flexibility. Robinson and Malhotra (2005) focus on quality management requirements of the new supply chain era and mention supply chain quality management concept, emphasizing the commitment to quality both inter- and intra-organizationally, again basing on the SCOR model and balanced scorecard approach. The paper provides a clear support for the need for further research in SC Quality management area. Wouters (2009) mentions the concept of 'enabling performance management', emphasizing the need for involvement of people at all levels, starting with the determination of the metrics. Challenges of performance measurement, need of developmental approach in performance measurement, importance of delegating the performance measurement at every level of hierarchy and the idea of 'metrics for people' are treated in detail. His previous work, Wouters and Wilderom (2008) is also referenced in this work and the study is critical in emphasizing the need for longitudinal case studies.

Stock et al. (2000) define the concept of 'fit' as the appropriate consistency between logistics practices and supply chain structures and investigates the impact of fit among channel governance, geographical dispersion and logistics integration on supply chain performance. Their study provides support for the importance of 'fit' among various supply chain parameters. Geiger et al. (2006) investigate the relationship of strategy/structure fit and firm performance using the mediating factor of 'industry concentration'. They reveal a clear need to analyze the effects of mediating factors other than industry concentration. Buttermann et al. (2008) present an application of 'fit' as Gestalt perspective to supply chain management. Fit is mentioned as 'mediation, moderation, matching, co variation, profile deviation and gestalts'. Their study applies fit as Gestalt perspective to search for archetypes or 'recurring clusters of attributes' which are directly related to the performance and the use of these archetypes as a means for classification of firm performance. Using a survey-based study, they identify six main archetypes: simple, low performers, market performers, average players, internally integrated low performers, masters of efficiency and two-time winners. It is emphasized that this is the first-time 'fit as gestalt concept' is applied to SCM.

This group of papers clearly indicates the need for having a broad, organization-wide perspective of the issue, highlighting the importance of consistency among various organizational factors. It also became apparent that the issue of 'fit' deserves further attention.

Chapter 3

KEY ISSUES IN SUPPLY CHAIN MANAGEMENT

In this section, we introduce some of the supply chain management issues. These issues span a large spectrum of a firm's activities, from the strategic through the tactical to the operational level:

• The ***strategic level*** deals with decisions that have a long-lasting effect on the firm. This includes decisions regarding product design, what to make internally and what to outsource, supplier selection, and strategic partnering as well as decisions on the number, location, and capacity of warehouses and manufacturing plants and the flow of material through the logistics network.

• The ***tactical level*** includes decisions that are typically updated anywhere between once every quarter and once every year. These include purchasing and production decisions, inventory policies, and transportation strategies, including the frequency with which customers are visited.

• The ***operational level*** refers to day-to-day decisions such as scheduling, lead time quotations, routing, and truck loading. Below we introduce and discuss some of the key issues, questions, and trade-offs associated with different decisions.

3.1) Distribution Network Configuration

Consider several plants producing products to serve a set of geographically dispersed retailers. The current set of warehouses is deemed inappropriate, and management wants to reorganize or redesign the distribution network. This may be due, for example, to changing demand patterns or the termination of a leasing contract for a number of existing warehouses. In addition, changing demand patterns may require a change in plant production levels, a selection of new suppliers, and a new flow pattern of goods throughout the distribution network. How should management select a set of warehouse locations and capacities, determine production levels for each product at each plant, and set transportation flows between facilities, either from plant to warehouse or warehouse to retailer, in such a way as to minimize total production, inventory, and transportation costs and satisfy service level requirements? This is a complex optimization problem, and advanced technology and approaches are required to find a solution.

3.2) Inventory Control

Consider a retailer that maintains an inventory of a particular product. Since customer demand changes over time, the retailer can use only historical data to predict demand. The retailer's objective is to decide at what point to reorder a new batch of the product, and how much to order so as to minimize inventory ordering and holding costs. More fundamentally, why should the retailer hold inventory in the first place? Is it due to uncertainty in customer demand, uncertainty in the supply process, or some other reasons? If it is due to uncertainty in customer demand, is there anything that can be done to reduce it? What is the impact of the forecasting tool used to predict customer demand? Should the retailer order more than, less than, or exactly the demand forecast? And, finally, what inventory turnover ratio should be used? Does it change from industry to industry?

3.3) Production Sourcing

In many industries, there is a need to carefully balance transportation and manufacturing costs. In particular, reducing production costs typically implies that each manufacturing facility is responsible for a small set of products so that large batches are produced, hence reducing production costs. Unfortunately, this may lead to higher transportation costs. Similarly, reducing transportation costs typically implies that each facility is flexible and has the ability to produce most or all products, but this leads to small batches and hence increases production costs. Finding the right balance between the two cost components is difficult but needs to be done monthly or quarterly.

3.4) Supply Contracts

In traditional supply chain strategies, each party in the chain focuses on its own profit and hence makes decisions with little regard to their impact on other supply chain partners. Relationships between suppliers and buyers are established by means of supply contracts that specify pricing and volume discounts, delivery lead times, quality, returns, and so forth. The question, of course, is whether supply contracts also can be used to replace the traditional supply chain strategy with one that optimizes the entire supply chain performance. In particular, what is the impact of volume discount and revenue-sharing contracts on supply chain performance? Are there pricing strategies that can be applied by suppliers to provide incentives for buyers to order more products while at the same time increasing the supplier profit?

3.5) Distribution Strategies

An important challenge faced by many organizations is how much should they centralize (or decentralize) their distribution system. What is the impact of each strategy on inventory levels and transportation costs? What about the impact on service levels? And, finally, when should products be transported by air from centralized locations to the various demand points? These questions are not only important for a single firm determining its distribution strategy, but also for competing retailers that need to decide how much they can collaborate with each other. For example, should competing dealers selling the same brand share inventory? If so, what is their competitive advantage?

3.6) Supply Chain Integration and Strategic Partnering

As observed earlier, designing and implementing a globally optimal supply chain is quite difficult because of its dynamics and the conflicting objectives employed by different facilities and partners. However, in today's competitive markets, most companies have no choice; they are forced to integrate their supply chain and engage in strategic partnering. This pressure stems from both their customers and their supply chain partners. How can integration be achieved successfully? Clearly, information sharing and operational planning are the keys to a successfully integrated supply chain. But what information should be shared? How should it be used? How does information affect the design and operation of the supply chain? What level of integration is needed within the organization and with external partners? Finally, what types of partnerships can be implemented, and which type should be implemented for a given situation?

3.7) Outsourcing and off shoring Strategies

Rethinking your supply chain strategy not only involves coordinating the different activities in the supply chain, but also deciding what to make internally and what to buy from outside sources. How can a firm identify what manufacturing activities lie in its set of core competencies, and thus should be completed internally, and what product and components should be purchased from outside suppliers, because these manufacturing activities are not core competencies? Is there any relationship between the answer to that question and product architecture? What are the risks associated with outsourcing and how can these risks be minimized? When you do outsource, how can you ensure a timely supply of products? And when should the firm keep dual sources for the same component? Finally, even if the firm decides not to outsource activities, when does it make sense to move facilities to the Far East? What are the impact of off shoring on inventory levels and the cost of capital? What are the risks?

3.8) Product Design

Effective design plays several critical roles in the supply chain. Most obviously, certain product designs may increase inventory holding or transportation costs relative to other designs, while other designs may facilitate a shorter manufacturing lead time. Unfortunately, product redesign is often expensive. When is it worthwhile to redesign products so as to reduce logistics costs or supply chain lead times? Is it possible to leverage product design to compensate for uncertainty in customer demand? Can one quantify the amount of savings resulting from such a strategy? What changes should be made in the supply chain to take advantage of the new product design? Finally, new concepts such as mass customization are increasingly popular. What role does supply chain management play in the successful implementation of these concepts?

3.9) Information Technology and Decision-Support Systems

Information technology is a critical enabler of effective supply chain management. Indeed, much of the current interest in supply chain management is motivated by the opportunities that appeared due to the abundance of data and the savings that can be achieved by sophisticated analysis of these data. The primary issue in supply chain management is not whether data can be received, but what data should be transferred; that is, which data are significant for supply chain management and which data can safely be ignored? How frequently should data be transferred and analyzed? What is the impact of the Internet? What is the role of electronic commerce? What infrastructure is required both internally and between supply chain partners? Finally, since information technology and decision-support systems are both available, can these technologies be viewed as the main tools used to achieve competitive advantage in the market? If they can, then what is preventing others from using the same technology?

Customer Value Customer value is the measure of a company's contribution to its customer, based on the entire range of products, services, and intangibles that constitute the company's offerings. In recent years, this measure has superseded measures such as quality and customer satisfaction. Obviously, effective supply chain management is critical if a firm wishes to fulfill customer needs and provide value. But what determines customer value in different industries? How is customer value measured? How is information technology used to enhance customer value in the supply chain? How does supply chain management contribute to customer value? How do emerging trends in customer value, such as development of relationships and experiences, affect supply chain management? What is the relationship between product price and brand name in the conventional world and in the online world?

3.10) Smart Pricing

Revenue management strategies have been applied successfully in industries such as airlines, hotels, and rental cars. In recent years, a number of manufactures, retailers, and carriers have applied a variation of these techniques to improve supply chain performance. In this case, the firm integrates pricing and inventory (or available capacity) to influence market demand and improve the bottom line. How is this done? Can "smart" pricing strategies be used to improve supply chain performance? What is the impact of rebate strategies on the supply chain? Each of these issues and strategies is discussed in great detail in the remaining chapters. As you will see, the focus in each case is on either the development chain or the supply chain and the focus is on achieving a globally optimized supply chain or managing risk and uncertainty in the supply chain, or both. A summary is provided in table 3.1.

S.no.	Issue	Chain	Global optimization	Managing risk and uncertainty
1.	Distribution network configuration	Supply	Y	
2.	Inventory control	Supply		Y
3.	Production sourcing	Supply	Y	
4.	Supply contracts	Both	Y	Y
5.	Distribution strategies	Supply	Y	Y
6.	Strategic partnering Development	Development	Y	
7.	Outsourcing	Development	Y	
8.	Product design	Development		Y
9.	Information technology	Supply	Y	Y
10.	Customer value Both	Both	Y	Y
11.	Smart pricing	Supply	Y	

Table (3.1):- Key supply chain management issues

3.11) KEY ISSUES IN AREA OF PERFORMANCE

The practical value in any model in management and business may be less in its predictive power and more in its ability to allow practitioners to reflect critically on reinterpret situations. Work is currently beginning to embody the framework in a computer-based diagnostic tool. As with most such tools, the goal will be less to capture definitive truth but to stimulate thought and debate. This area will overlap with the development of tools to allow the modeling of supply chain structure. In particular this area will overlap with the development of tools to allow the modeling of supply chain structures. In particular this work will explore the relationships between different styles of co-operation and patterns of buyer-seller interconnections.

3.11.1) Effect of inter-organizational integration on performance

All the research studies employed a cross-sectional research design; there could be a time lag between the organizations integrating information systems and the realization of tangible benefits.

A longitudinal research design could provide more insight into the relationships. IOIS and inter-organizational activities significantly influence the organization but, it is not clear at what level of integration can maximum benefits is achieved.

No literature is available on assessment of the influence of integration at basic, intermediate and integration stages. Study is needed to streamline the flow of material, information and cash, simplify the decision making procedure and eliminate non-value adding activities to increase upon the performance of the supply chain.

Each organization needs to capitalize on supply chain capabilities and resources to bring products and services to the market faster, at the lowest possible cost, with the appropriate product/service features and the best overall value. The future research holds out or point towards intermediate lean international supply chain.

3.11.2) SCM models-integration-analysis scope

Considering computational and derivability complexity of the decision models is essential to develop efficient algorithms and meta-heuristic approaches capable of providing good approximations of Pareto-optimal solutions in a short span of time.

Almost half of the previous models and algorithms have been tested on artificial data /synthetic data sets. This indicates another important avenue for further research that is to apply these existing methodologies on real-life data sets to examine their applicability in practice.

Research should go beyond viewing supply chain management in an atomistic/smaller or linear fashion which is particularly important in studying SCM. While research using social network theory does address multidirectional flows of communication of supply chain, structuration theory is a more appropriate theory for incorporating the unique values of sustainable organizations and emergent supply chain structures. Supply chain network is complicated by the difficulty in defining system boundaries and further work in network definitions may contribute to the development of supply chain network theory.

3.11.3) Control-methodologies

More recently, highly sophisticated optimal control tool/methods have been proposed mainly leased on the time domain. But the reports state that the majority of companies worldwide still suffer from poor SCM and the highly undesired phenomena such as "bull-whip effect" have not been remedied which puts a question mark on the applicability of control methodologies in real life supply chain problems.

As the assumptions on which various methodologies are based do not exist in real life problems like;-

a) Lead times are not fixed and not known with accuracy.

b) Inventory levels should be bounded below by zero and above by warehouse capacities these bounds are never taken into account etc.

c) Single stage system are usually studied, assuming production of a single product or aggregated production. In real life systems various products are produced with different production rates and different lead times-which share common tools and storage and machines.

Horizontal integration is often represented by considering the supply chain stages in raw-while interconnections between different level and same level stages are ignored. Raw materials costs which may be variable, labor costs, inventory costs are rarely taken explicitly into account.

The mechanism of coordination need to be studied in detail. The co-ordination mechanisms can further be of different sub types. To co-ordinate the whole supply chain, the aggregation of the impact of all co-ordination mechanisms and systems on the performance of supply chain is required. Various combinations can be carried out/explored with the help of simulation.

3.11.4) Interaction with suppliers:-

Potentially rich research endeavor would be to assess the relationship between strategic fit in supply chain, through the assessment of the degree of alignment of competitive priorities and firm performance. Study have shown that if the alignment of the manufacturing strategy with competitive priorities leads to improved performance , it would be interesting to analyze the impact of reducing the gap between customer requirements and those imposed on suppliers on the performance of the company.

A very little research has investigated the distribution of gains generated from a better alignment in the supply chain. Defining the way of nature of communication mechanisms adopted by the business partners. Do companies with stronger co-operative practices have distinct behavior with regard to communication mechanisms?

3.11.5) Influence of ICT on SCM Management and Performance

A first implication relates to methodology and measurement. Earlier research (Chen and Paulraj, 2004) has already aimed at establishing proven scales and constructs in SCM. Our present review once more points at that as a major area of attention for future research. Our field can be brought forward by using existing items, scales, and constructs. That will enable comparison of different studies. While this has been noticed, but not implemented in the SCM area, it is also needed in the field of ICT. While using more existing and better validated scales would help, there are also concerns with respect to the use of single respondents, subjective scales, and self-reported performance results (see Forza (2002), for an operations management-related discussion and Nunnally (1978) for a more general discussion). Possible remedies consist of the extension of existing methods and methodologies, e.g. with the use of additional external, archival data from publicly available sources or the use of multiple respondents from different partners in the chain. However, we realize that in many cases that will be very hard.

A second, related point is the conceptualization and measurement of ICT. We need to realize that ICT is not a single technology or holistic concept. Das and Nair (2010) offer an interesting list of information technologies in different manufacturing stages: design, production, and planning. That variety is hardly reflected in the current studies. We need to better investigate the effects of single technologies such as ERP, EDI, or internet; their interrelation and joint effect. Additionally; intra- and inter-organizational ICT need to be studied by addressing questions like what are the separate effects of intra and inter-organizational ICT and how do they interact with SCM practices and with each other. Such research could possibly also try to detect how different technologies influence different aspects of performance. Our review suggests, for example that ERP systems do not have a direct impact on general performance measures, but they might have a positive effect on a specific aspect such as reliable deliveries.

A third implication and suggestion for future work is to rethink and broaden our view on how ICT and SCM influence performance, how they interact and what their joint effect is. Most research considers only the effect of ICT via SCM (mediation) on performance. Future research should aim at following Jeffers et al. (2008) in their conceptualization of SCM as a moderator of the relationship between ICT and performance. That reflects that positive effects of ICT can only be reached by implementing appropriate SCM practices. Vickery et al. (2010) show that there is no separate effect of ICT and SCM, while there is a joint effect. Similarly, in line with our second point, we need to investigate whether different models describe how SCM practices interact with different types of ICT, e.g. intra- and inter-organizational ICT systems. Moreover, contextual variables need to be further incorporated to explore contingencies in the application of ICT and SCM and their relationship, in line with a recommendation for further research of Rosenzweig (2009).

A fourth point is to incorporate organizational aspects. A recent case study by Ambrose et al. (2008) shows that the dynamics and interactions between SCM, and the use of certain ICT are also influenced by the development of the relationship between both the organizations and the persons interacting. Future research should aim at capturing such human and organizational issues as well. A related issue, as pointed out earlier, is to explore how ICT can be turned into a capability of a company, following the RBV of the firm. Understanding such organizational aspects will be beneficial for getting organizations out of there ICT crises.

As might be concluded from the above recommendations, there is not yet a study that comprises all characteristics that we would like it to have. Ideally, future research should include a comprehensive list of ICT (as in Das and Nair, 2010) or a well-motivated subset of that list, a set of SCM practices (Chen and Paulraj, 2004) and would investigate the effect of the interaction between those subsets (as in Vickery et al., 2010) on various performance measures. Alternatively, based on theoretical considerations, researchers can make a choice and investigate single ICT-technologies' effect on performance, if supported by SC practices. Following Rosenzweig (2009), it is clear those contingencies need to be incorporated. Some recent papers have made a step towards realizing some of the above-mentioned directions of future research. Tan et al. (2010) and Vickery et al. (2010) show that there is no direct effect of EDI, but there is a mediated or moderated effect through a SC practice, which shows the importance of adapting organizational practices. Rosenzweig (2009) shows the effect of contextual factors. As such these papers are exemplars for current and future research. As indicated above, much more is needed. The above analysis gives a number of future research possibilities, guidelines, and directions.

Chapter 4

Methodology

4.1).Graph Theory:-

Definition of a graph

A graph G comprises a set V of vertices and a set E of edges Each edge in E is a pair (a, b) of vertices in V If (a,b) is an edge in E, we connect a and b in the graph drawing of G,V={1, 2,3,4,5,6,7} E={(1,2),(1,3),(2,4). 1 (4,5),(3,5),(4,5), 2 3 (5, 6), (6,7)

Size and order

The size of G is the number n of vertices in V The order of G is the number L of edges in E Minimum possible order is 0 (empty graph) Maximum possible order is n(n-1)/2 (complete graph)

Adjacency matrix for a graph

The adjacency matrix x =[xab] for G is a matrix with n rows and n columns and entries given by:
xab = 1 if (a,b) is an edge in G
0 otherwise

Degrees and degree sequence

The degree da of vertex a is the number of vertices to which a is linked by an edge
The minimum possible degree is 0

Subgraphs

A subgraph of G=G(V,E) is a subset W of the vertex set V together with all of the edges that connect pairs of vertices in W The maximum possible degree is n-1
The degree sequence for a graph is the vector (d1, d2,…, dn)
Subgraph counts: the dyad census
The graph G has n(n-1)/2 subgraphs of size 2 each subgraph of size 2 comprises a pair of vertices, and the edge between them is either present or absent:

Paths

A path from vertex a to vertex b is an ordered sequence a=v0, v1, …, vm=b of distinct vertices in which each adjacent pair (vj-1,vj) is linked by an edge. The length of the path is m

Reach ability and connectedness

If there is a path from vertex a to vertex b, a is reachable from b If each vertex in G is reachable from each other vertex, then G is connected
A component of G is a maximal connected subgraph (i.e. a connected subgraph with vertex set W for which no larger set Z containing W is connected)

4.2 Digraphs

In some problems the relation between the objects is not symmetric. For these cases we need directed graphs, where the edges are oriented from one vertex to another. As an example consider a map of a small town. Can you make the streets one-way, and still be able to drive from one house to another (or exit the town)?

Definitions

DEFINITION. A **digraph** (or a **directed graph**) $D = (VD, ED)$ consists of the vertices VD and (directed) edges $ED \subseteq VD \times VD$ (without loops vv). We still write uv for (u, v), but note that now $uv \neq vu$. For each pair $e = uv$ define the **inverse** of e as $e^{-1} = vu$ $(= (v, u))$.

Note that $e \in D$ does *not* imply $e^{-1} \in D$.

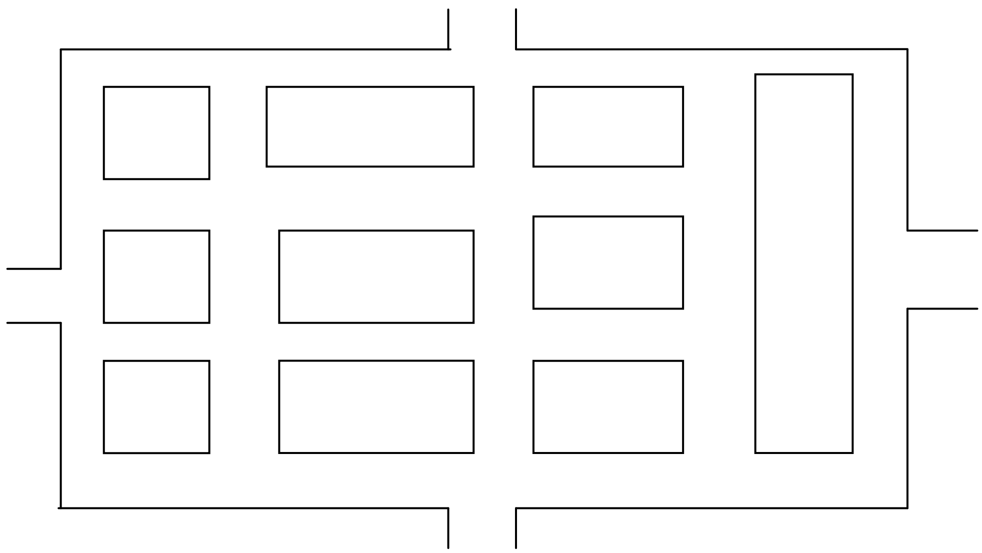

Fig.4.1 Map of a small town

DEFINITION. Let D be a digraph. Then A is its

• **Subdigraph**, if $VA \subseteq VD$ and $EA \subseteq ED$,

• **Induced subdigraph**, $A = D[X]$, if $VA = X$ and $EA = ED \cap (X \times X)$.

The **underlying graph** $U(D)$ of a digraph D is the graph on VD such that if $e \in D$, then the undirected edge with the same ends is in $U(D)$.

A digraph D is an **orientation** of a graph G, if $G = U(D)$ and $e \in D$ implies $e^{-1} \notin D$. In this case, D is said to be an **oriented graph**.

DEFINITION. Let D be a digraph. A walk $W = e_1e_2 \ldots e_k\colon u \overset{\star}{\longrightarrow} v$ of $U(D)$ is a **directed walk**, if $e_i \in D$ for all $i \in [1, k]$. Similarly, we define **directed paths** and **directed cycles** as directed walks and closed directed walks without repetitions of vertices.

The digraph D is **di-connected**, if, for all $u \neq v$, there exist directed paths $u \overset{\star}{\rightarrow} v$ and $v \overset{\star}{\rightarrow} u$. The maximal induced di-connected sub digraphs are the **di-components** of D. Note that a graph $G = U(D)$ might be connected, although the digraph D is not di-connected.

DEFINITION. The **in degree** and the **out degree** of a vertex are defined as follows

$dID(v) = |\{e \in D \mid e = xv\}|$, dO
$D(v) = |\{e \in D \mid e = vx\}|$.
We have the following **handshaking lemma**. (You offer and accept a handshake.)
Lemma . *Let D be a digraph. Then*

$$\sum_{v\in D} dID(v) = |D| = \sum_{v\in D} d\,OD(v)$$

4.3 Directed paths

The relationship between paths and directed paths is in general rather complicated. This digraph has a path of length five, but its directed paths are of length one. There is a nice connection between the lengths of directed paths and the chromatic number $c(D) = c(U(D))$.

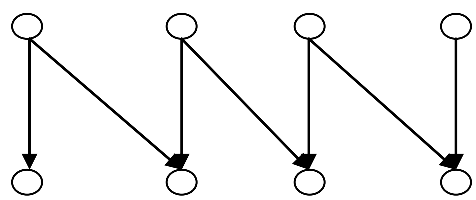

Fig. 4.2:- Showing directed paths

Theorem (*A digraph D has a directed path of length* $\chi(D) - 1$.
Proof. Let $A \subseteq ED$ be a minimal set of edges such that the sub-digraph $D-A$ contains no directed cycles. Let k be the length of the longest directed path in $D-A$. For each vertex $v \in D$, assign a color $a(v) = i$, if a longest directed path from v has length $i - 1$ in $D-A$. Here $1 \le i \le k + 1$. First we observe that if $P = e1e2 \ldots er$ ($r \ge 1$) is any directed path $u \star \longrightarrow v$ in $D-A$, then $a(u) \ne a(v)$. Indeed, if $a(v) = i$, then there exists a directed path Q: $v \star\!\!\longrightarrow w$ of length $i - 1$, and PQ is a directed path, since $D-A$ does not contain directed cycles. Since PQ: $u \star\!\!\longrightarrow w$, $a(u) \ne i = a(v)$. In particular, if $e = uv \in D-A$, then $a(u) \ne a(v)$.
Consider then an edge $e = vu \in A$. By the minimality of A, $(D-A)+ e$ contains a directed cycle C: $u \star\!\!\longrightarrow v \longrightarrow u$, where the part $u \star\!\!\longrightarrow v$ is a directed path in $D-A$, and hence $a(u) \ne a(v)$. This shows that a is a proper coloring of $U(D)$, and therefore $\chi(D) \le k + 1$, that is, $k \ge \chi(D) - 1$.The bound $\chi(D) - 1$ is the best possible in the following sense:

Theorem . *Every graph G has an orientation D, where the longest directed paths have lengths* $\chi(G) - 1$.

Proof. Let $k = \chi(G)$ and let a be a proper k-coloring of G. As usual the set of colors is $[1, k]$. We orient each edge $uv \in G$ by setting $uv \in D$, if $a(u) < a(v)$. Clearly, the so obtained orientation D has no directed paths of length $\geq k - 1$.
DEFINITION. An orientation D of an undirected graph G is **acyclic**, if it has no directed cycles. Let $a(G)$ be the number of acyclic orientations of G. The next result is charming, since $cG(-1)$ measures the number of proper colorings of G using -1 colors!

Theorem . *Let G be a graph of order n. Then the number of the acyclic orientations of G is*
$a(G) = (-1)n\chi G(-1)$,
where χG is the chromatic polynomial of G.

Proof. The proof is by induction on εG. First, if G is discrete, then $\chi(k) = k^n$, and $a(G) = 1 = (-1)^n(-1)^n = (-1)\chi G(-1)$ as required.
Now $\chi(k)$ is a polynomial that satisfies the recurrence $\chi G(k) = \chi G\text{-}\ e(k)\ - \chi G{*}e(k)$. To prove the claim, we show that $a(G)$ satisfies the same recurrence. Indeed, if

$$a(G) = a(G-e) + a(G * e) \qquad (4.1)$$

then, by the induction hypothesis,
$a(G) = (-1)n\chi G{-}e(-1) + (-1)^{n-1}\chi G{*}e(-1) = (-1)n\chi G(-1)$

For (4.3), we observe that every acyclic orientation of G gives an acyclic orientation of $G-e$. On the other hand, if D is an acyclic orientation of $G-e$ for $e = uv$, it extends to an acyclic orientation of G by putting $e1 : u \rightarrow v$ or $e2 : v \rightarrow u$. Indeed, if D has no directed path $u \star\!\!\rightarrow v$, we choose $e2$, and if D has no directed path $v \star\!\!\rightarrow u$, we choose $e1$. Note that since D is acyclic, it cannot have both ways $u \star\!\!\rightarrow v$ and $v \star\!\!\rightarrow u$.
We conclude that $a(G) = a(G-e) + b$, where b is the number of acyclic orientations D of $G-e$ that extend in both ways $e1$ and $e2$. The acyclic orientations D that extend in both ways are exactly those that contain neither
$u \star\!\!\rightarrow v$ nor $v \star\!\!\rightarrow u$ as a directed path. (4.2)
Each acyclic orientation of $G * e$ corresponds in a natural way to an acyclic orientation D of $G-e$ that satisfies (4.2). Therefore $b = a(G * e)$, and the proof is completed.

4.4 One-way traffic

Every graph can be oriented, but the result may not be di-connected. In the **one way traffic problem** the resulting orientation should be di-connected, for otherwise someone is not able to drive home.
DEFINITION. A graph G is **di-orientable**, if there is a di-connected oriented graph D
such that $G = U(D)$.

Theorem *A connected graph G is di-orientable if and only if G has*
no bridges.
Proof. If G has a bridge e, then any orientation of G has at least two di-components (both sides of the bridge).
Suppose then that G has no bridges. Hence G has a cycle C, and a cycle is always di orientable. Let then $H \subseteq G$ be maximal such that it has a di-orientation DH. If

H = *G*, then we are done.

Otherwise, there exists an edge $e = vu \in G$ such that
$u \in H$ but $v \notin H$ (because *G* is connected). The edge *e* is not a bridge and thus there exists a cycle
$C' = ePQ$: $v \longrightarrow u \star\!\!\longrightarrow w \star\!\!\longrightarrow v$
in *G*, where *w* is the last vertex inside *H the di-orientation DH of H there is a directed path*

P′ : u→ w. Now, we orient*

*e : v → u and the edges of Q in the direction Q: w *→ v to obtain a directed cycle eP'Q: v → u *→ w *→ v. In conclusion, G[VH ∪ VC] has a di-orientation, which contradicts the maximality assumption on H. This proves the claim.*

4.5 Flows

DEFINITION. A network N consists of

- An underlying digraph D = (V, E),
- Two distinct vertices s and r, called the source and the sink of N, and
- A capacity function a: $V \times V \rightarrow R+$ (nonnegative real numbers), for which a(e) = 0, if $e \notin E$.

Denote VN = V and EN = E.
Let $A \subseteq VN$ be a set of vertices, and f : $VN \times VN \rightarrow R$ any function such that f (e) = 0, if $e \notin N$. We adopt the following notations:

$[A, A^1] = \{e \in D \mid e = uv, u \in A, v \notin A^1\}$,

$f^+(u) = \sum_{v\in N} f(uv)$ and f (uv) and $f^-(u) = \sum_{v\in N} f(vu)$

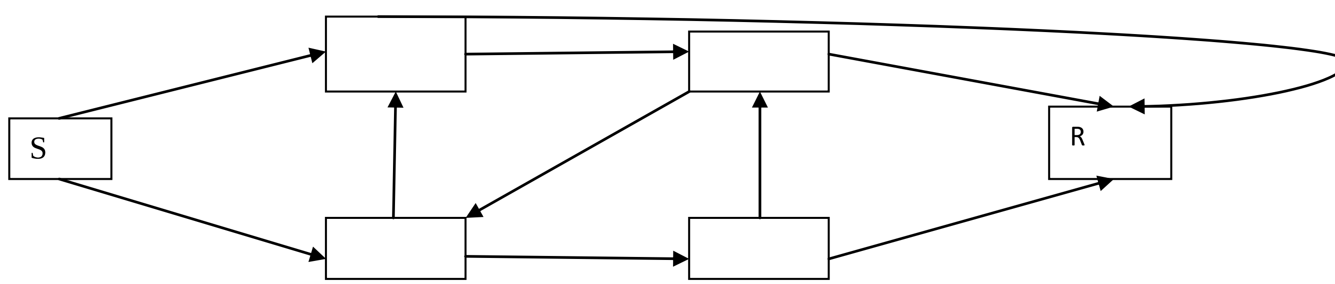

Fig. 4.3:- Network flows

DEFINITION. A flow in a network N is a function f : $VN \times VN \rightarrow R+$ such that

$0 \leq f(e) \leq a(e)$ for all e, and $f^-(v) = f^+(v)$ for all $v \notin \{s, r\}$.

A flow f in N is something that the network can handle. *E.g.*, in the above figure the source should not try to feed the network the full capacity (11 $m3$/min) of its pipes, because the junctions cannot handle this much water.

DEFINITION. Every network N has a **zero flow** defined by $f(e) = 0$ for all e. For a flow f and each subset $A \subseteq VN$, define the **resultant flow from** A and the **value** of f as the numbers
$\mathrm{val}(fA) = f^+(A) - f^-(A)$ and $\mathrm{val}(f) = \mathrm{val}(fs)$ $(= f^+(s) - f^-(s))$.
A flow f of a network N is a **maximum flow**, if there does not exist any flow f' such that $\mathrm{val}(f) < \mathrm{val}(f')$.
The value $\mathrm{val}(f)$ of a flow is the overall number of goods that are (to be) transported through the network from the source to the sink. In the above example, $\mathrm{val}(f) = 9$.

Lemma. *Let* $N = (D, s, r, a)$ *be a network with a flow* f.
(i) If $A \subseteq N \setminus \{s, r\}$, *then* $\mathrm{val}(fA) = 0$.
(ii) $\mathrm{val}(f) = -\mathrm{val}(fr)$.

Proof. Let $A \subseteq N \setminus \{s, r\}$. Then

$$0 = \sum(v \in A)\, f^+(v) = \sum(v \in A)\, f^-(v) - \sum(v \in A)\, f^+(v) = f^+(A) - f^-(A) = \mathrm{val}(f_A)$$

Where the third equality holds since the values of the edges uv with $u, v \in A$ cancel each out. The second claim is also clear.

Chapter 4 (a)

MULTI-ATTRIBUTE DECISION MAKING: A CLASSIFICATION OF METHODS

MADM methods can be classified as to whether if they are non compensatory or compensatory. The decision maker may be of the view that high performance relative to one attribute can at least partially compensate for low performance relative to another attribute, particularly if an initial screening analysis has eliminated alternatives that fail to meet any minimum performance requirements. Methods that incorporate tradeoffs between high and low performance into the analysis are termed “compensatory.” Those methods that do not are termed “non compensatory.” In their book, Hwang and Yoon (1981) give 14 MADM methods. These methods are explained briefly below

4(a).1 Dominance

An alternative is “dominated” if another alternative outperforms it with respect to at least one attribute and performs equally with respect to the remainder of attributes. With the dominance method, alternatives are screened such that all dominated alternatives are discarded. The screening power of this method tends to decrease as the number of independent attributes becomes larger.

4(a).2 Maximin

The principle underlying the maximin method is that “a chain is only as strong as its weakest link.” Effectively, the method gives each alternative a score equal to the strength of its weakest link, where the “links” are the attributes. Thus, it requires that performance with respect to all attributes be measured in commensurate units (very rare for MADM problems) or else be normalized prior to performing the method.

4(a).3 Maximax

The viewpoint underlying the maximax method is one that assigns total importance to the attribute with respect to which each alternative performs best. Extending the “chain” analogy used in describing the maximin method, maximax performs as if one was comparing alternative chains in search of the best link. The score of each chain (alternative) is equal to the performance of its strongest link (attribute). Like the maximin method, maximax requires that all attributes be commensurate or else prenormalized.

4(a).4 Conjunctive (Satisfying)

The conjunctive method is purely a screening method. The requirement embodied by the conjunctive screening approach is that to be acceptable, an alternative must exceed given performance thresholds for all attributes. The attributes (and thus the thresholds) need not be measured in commensurate units.

4(a).5 Disjunctive

The disjunctive method is also purely a screening method. It is the complement of the conjunctive method, substituting “or” in place of “and.” That is, to pass the disjunctive screening test, an alternative must exceed the given performance threshold for at least one attribute. Like the conjunctive method, the disjunctive method does not require attributes to be measured in commensurate units.

4(a).6 Lexicographic

The best-known application of the lexicographic method is, as its name implies, alphabetical ordering such as is found in dictionaries. Using this method, attributes are rank-ordered in terms of importance. The alternative with the best performance on the most important attribute is chosen. If there are ties with respect to this attribute, the next most important attribute is considered, and so on. Note two important ways in which MADM problems typically differ from alphabetizing dictionary words. First, there are many fewer alternatives in a MADM problem than words in the dictionary. Second, when the decision matrix contains quantitative attribute values, there are effectively an infinite number [rather than 26 (i.e., A-Z)] of possible scores with a correspondingly lower probability of ties.

4(a).7 Lexicographic Semi-Order

This is a slight variation on the lexicographic method, where “near-ties” are allowed to count as ties without any penalty to the alternative, which scores slightly lower within the tolerance (“tie”) window. Counting near ties as ties makes the lexicographic method less of a “knife-edged” ranking method and more appropriate for MADM problems with quantitative data in the decision matrix. However, the method can lead to intransitive results, wherein A is preferred to B, B is preferred to C, but C is preferred to A.

4(a).8 Elimination by Aspects

This method is a formalization of the well-known heuristic, “process of elimination.” Like the lexicographic method, this evaluation proceeds one attribute at a time, starting with attributes determined to be most important. Then, like the conjunctive method, alternatives not exceeding minimum performance requirements—with respect to the single attribute of interest, in this case—are eliminated. The process generally proceeds until one alternative remains, although adjustment of the performance threshold may be required in some cases to achieve a unique solution.

4(a).9 Linear Assignment Method

This method requires, in addition to the decision matrix data, cardinal importance weights for each attribute and rankings of the alternatives with respect to each attribute. These information requirements are intermediate between those of the eight methods described previously, and the five methods that follow, in that they require ordinal (but not cardinal) preference rankings of the alternatives with respect to each attribute. The primary use of the additional information is to enable compensatory rather than non compensatory analysis that is, allowing good performance on one attribute to compensate for low performance on another. Note at this point that quantitative attribute values (data in the decision matrix) do not constitute cardinal preference rankings. Attribute values are generally non commensurate across attributes, preference is not necessarily linearly increasing with attribute values, and preference for attribute values of zero is not generally zero. However, as long as the decision maker can specify an ordinal correspondence between attribute values and preference, such as "more is better" or "less is better" for each attribute, then the ordinal alternative rankings with respect to each attribute that are needed by the linear assignment method are specified uniquely. Thus, the evaluation/performance rankings required by the linear assignment method are easier to derive than the evaluation/performance ratings required by the five methods that follow. The cost of using ordinal rankings rather than cardinal ratings is that the method is only "semi-compensatory," in that incremental changes in the performance of an alternative will not enter into the analysis unless the changes are large enough to alter the rank order of the alternatives.

4(a).10 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

The principle behind TOPSIS is simple: The chosen alternative should be as close to the ideal solution as possible and as far from the negative-ideal solution as possible. The ideal solution is formed as a composite of the best performance values exhibited (in the decision matrix) by any alternative for each attribute. The negative-ideal solution is the composite of the worst performance values. Proximity to each of these performance poles is measured in the Euclidean sense (e.g., square root of the sum of the squared distances along each axis in the "attribute space"), with optional weighting of each attribute.

4(a).11 Multiple Attribute Utility Models

Utility theory describes the selection of a satisfactory solution as the maximization of satisfaction derived from its selection. The best alternative is the one that maximizes utility for the decision maker's stated preference structure. Utility models are of two types additive and multiplicative utility models. The main steps in using a multi-attribute utility model can be counted as 1) determination of utility functions for individual attributes, 2) determination of weighting or scaling factors, 3) determination of the type of utility model, 4) the measurement of the utility values for each alternative with respect to the considered attributes, and 5) the selection of the best alternative.

4(a).12 Data Envelopment Analysis

Data envelopment analysis (DEA) is a nonparametric method of measuring the efficiency of a decision making unit such as a firm or a public-sector agency, which was first introduced into the operations research literature by Charnes et al. (1978). DEA is a relative, technical efficiency measurement tool, which uses operations research techniques to automatically calculate the weights assigned to the inputs and outputs of the production units being assessed. The actual input/output data values are then multiplied with the calculated weights to determine the efficiency scores. DEA is a nonparametric multiple criteria method; no production, cost, or profit function is estimated from the data.

Chapter 5

Modeling and integrative analysis of supply chain using graph theoretic approach

5.1. Introduction

The enormous literature on supply chain strategy since long has recognize supply chain as a potent competitive weapon and the importance of the supply chain system management at the corporate level has already been highlighted from as early as 2006s (Skinner, 2006; Buffa, 2004; Hayes and Wheelwright, 2004; Hayes et al., 2004; Hill, 2004). Ever changing products, technology competitors make the supply chain a challenging task of responding to market opportunities and all these turbulent situations became more vigorous with increasing levels of globalization (Handifield and Nichols, 2005). Effective and efficient supply chain system management can have a dramatic positive impact on firm's competitiveness in dealing with these volatile market situations and this is possible through comprehensive system wide analysis of the total supply chain system (Cleveland et al., 2005; Voss and Blackmon, 2004; Vickery et al., 2003; Ward et al., 2004; Kadipasaoghi et al., 2008). In the existing models of supply chain system analysis, the decisions are taken in an isolated way and the broader system wide effects cannot be analyzed (Sarmiento et al., 2007). Supply chain performance is measured without a broad perspective of system wide effects (Gomes et al., 2006) With the ever increasing competition in the recent times, the phenomenon of rapid change in market conditions has even aggravated (Alvi and Labib, 2004; Pun, 2005; Ramesh and Devadasan, 2007).

Comprehensiveness of the model may be referred to as how many of the important phenomena in the factory environments are considered in the construction of the analytical model. Increasing the comprehensiveness of the supply chain system models has always remained the primary challenge for the supply chain system researchers (Gershwin, 2005; Kadipasaoghi et al., 2006; Arora and Kumar, 2008). Models have already been developed that predict, with sufficient accuracy the measures of the supply chain system such as production rate, average inventory and average lead time and the like. Optimization models like linear programming, integer programming have limitations for total supply chain system analysis as there are large number of variables and constraints involved causing a heavy computational burden (Blackhurst et al., 2005).

Even the practices of TQM, JIT and lean supply chain call for the integrated analysis of the supply chain systems (Shah and Ward, 2003). Bourne et al. (2005) have investigated the interactive role of performance measures on the supply chain system and calls for a quantitative analysis of the issue. Gomes et al. (2006) also point to the lack of broad perspective in the traditional supply chain performance measures. The limitations of various existing models in respect of total analysis of supply chain system call for a structure-based system model, which is capable of incorporating the interactions and interdependences between various subsystems. Though, event tree and fault tree methods, cause-consequence diagrams, Markov models, etc. are structure based and incorporate topology and interactions of the systems, but are limited to first neighbor connection only (Gandhi et al., 2009).

To fill this research gap, a graph theory-based supply chain system model is proposed, which has a capability to address the issues of integration of analysis. The model can include all the subsystems along with the interactions therein and thus becomes a tool for total supply chain system analysis. These kinds of models have already been applied extensively to analyze other complex engineering systems such as power plants (Mohan et al., 2006) and composites materials (Durai Prabhakaran et al., 2006). The proposed model will be useful for analyzing, evaluating and designing a supply chain system at the conceptual stage. It can be used to stream line the supply chain system processes for sustainable production (Liyanage, 2007). The methodology suggested in this chapter can be classified as a pure modeling approach, which has been advocated for large and complex systems such as a supply chain system (Blackhurst et al., 2005). It means that the optimization-related components are not directly incorporated in this model. Rather, it aims to support managers for decision making by providing various important insights into the total supply chain system. These important insights maybe used by the managers or other decision makers to understand the current situations and determine improvements to be made.

Nomenclature:-

G =supply chain system graph

V = set of vertices

E = set of edges

S_1=input subsystem

S_2= management subsystem

S_3 = supply chain process subsystem

S_4 =support subsystem

S_5 =output subsystem

e_{ij}= influence/interaction of subsystem Si to subsystem Sj

L_{ijk} =interaction loop among subsystems Si, Sj and Sk

J_{kl} = number of elements in the lth subgroup of the kth group in the permanent multinomial

A = supply chain system adjacency matrix

B = supply chain system characteristic matrix

C = supply chain subsystem characteristic and interaction variable matrix

D = supply chain subsystem characteristic diagonal matrix

E = interaction variable matrix

P_{S1} = supply chain subsystem permanent matrix

P_{S2}= permanent matrix for input subsystem structure

P_{S3}= permanent matrix for management subsystem structure

P_{S3}= permanent matrix for supply chain process subsystem structure

P_{S4} =permanent matrix for support subsystem structure

P_{S5} = permanent matrix for output subsystem structure

5.2. Assumptions for developing graph theory theoretic model

The proposed graph theoretic model for supply chain systems is based on some assumptions as listed below:-

The structure of the system can be correlated quantitatively with its performance e.g.:- productivity, quality, reliability, etc.

The interactions as well as the subsystems discussed in the chapter are assumed for a general supply chain system. The subsystems must be identified separately for applying the model to any specific supply chain system.

Total supply chain system, its subsystems and their interactions for the organization under consideration depend upon its aims and objectives, value system and business strategy.

Variable permanent matrix is capable of strong complete information related to a real life situation of a typical supply management system as all its elements are variables and functions of characterizing attributes. This is possible by associating a vector of attributes representing subsystems (i.e. diagonal elements) and interconnections (i.e. off-diagonal elements) and interconnections (i.e. off-diagonal elements). These attribute, if identified comprehensively, the matrix represents the supply chain system completely.

Permanent function of the variable permanent matrix characterizes uniquely the supply chain system completely.

Agile supply chain, lean supply chain and integrated management systems can be derived from the total supply chain system through structural manipulations of the subsets of variable permanent matrix and its permanent function.

Performance of a supply chain system depends on individual performance of subsystems, sub systems and their components along with interactions/interdependences between them.

Modeling/methodology is based on bottom up approach. Permanent function values of sub-subsystems are used in permanent matrices of subsystems permanent function values of overall supply chain system.

The experts may assign correct and representative numerical score to the elements of the supply chain system at the lowest in a particular dimension of performance.

5.3. Identification of subsystems of the supply chain system

For description of the methodology, five subsystems have been identified namely input, management, supply chain process, support and output subsystems. This is a representative assumption for a general supply chain system and all the important criteria governing the supply chain system behavior are reflected in these subsystems. These subsystems may not be universal and there may be some variations for modelling specific supply chain systems. However, the proposed model has the capability to consider any such variation and is suitable for modeling any particular supply chain system structure. The following sections discuss the importance of each of the identified subsystems of the supply chain system.

Input subsystem

Various types of inputs for a general supply chain system may be listed as raw materials, suppliers and vendors, capital, design engineering and the business environment. The reliable relations and the resources available with the supplier such as sophisticated technology and information system influence the competitiveness of the supply chain system to a great extent. The practices followed in the design department are a deciding factor in the overall competitive position of a supply chain system as there is a strong relation between product development time and the increased market share (Carter and Baker, 2006; Blackwell, 2007). The other input of capital availability is observed as one of the success factors for the business.

Management subsystem

Kristensen et al. (2001) recognize that overall business excellence is a function of effective use of all the subsystems of the supply chain systems in an intellectual manner and management subsystem has this responsibility. Management subsystem makes the analysis of the current business environment in terms of the opportunities or threats for the organization and also identifies specific strengths and weaknesses of the entire system and thus develops a strategy to steer the organization to success. It takes corrective actions where ever necessary after obtaining the feedback and also, it makes available the requisite resources to various departments of the supply chain system. It conducts several performance appraisals, both of functional departments and the individuals working in them separately. The management subsystem has the responsibility of building quality culture in all subsystems of the supply chain system.

Supply chain process subsystem

The role of supply chain process subsystem for providing a cutting edge to the total business cannot be ignored in the era of globalization and dynamic markets. Different types of flexibilities such as new product introduction, volume flexibility and product flexibility play the role of strategic importance in dealing with turbulent markets (Petrony and Bevilacqua, 2002). Supply chain proactivity, which has been defined as a tendency of a company to implement the most modern and advanced production management practices has been found to have deep impact on business performance (Benito, 2005). Several proactive dimensions are supply chain involvement, commitment to supply chain technology advancements, multi-skilled workforce development and supply chain's integration with market and design functions (Chang et al., 2005). The supply chain practices followed in a factory define the levels competence of the total business (Magnan et al., 2007). The importance of humans as important player in the supply chain system structure has been recognized from a long time (Oakland and Oakland,2006). Proactive behavior of people plays a great role in distinguishing successful companies from the others. Thus, the elements of the supply chain process subsystem may be summarized as machines and equipments, human resources, material handling systems, layout and work environment.

Support subsystem

System operation requires information gathering and communication for operation of total supply chain system (Milner and Kouvelis, 2002; Raghunathan, 2001; Lee et al., 2000). The huge leaps in information technology development have made the supply chain organizations to deploy very powerful information and communication infrastructure. The accuracy, timeliness and reliability of the information shared between different functional departments or subsystems of the supply chain system influence the performance of an organization. Main areas of sharing information are inventories, sales, demand forecasts, order status and production schedules (Lee et al., 2005). Timely communication of the production schedule ensures appropriate utilization of the equipments and the customer satisfaction is achieved. Using modern day information technology tools, different "what-if" scenarios for analysis and decision making may be developed to aid management in the complex process of decision making. The supply chain system can meet the schedule requirements if the equipments are available in good conditions. Even best of the equipments may perform poorly and may depreciate quickly if not maintained properly and timely. The maintenance function is responsible for keeping the equipment in appropriate working conditions with high degree of reliability. The proactive and preventive measures, degree of restoration to original condition, availability level of equipment and mean time to repair describe the performance of maintenance function. Similarly, the accounting and finance divisions allocate the funds for specific purposes to all the subsystems and keeps a record for its utilization. Thus, the subsystem supports the management and the other subsystems for their respective operations. The main constituents are summarized as information processing department, maintenance department and the accounts and finance.

Output subsystem

The dynamic nature of today's global market makes a firm's ability to anticipate and to respond to customer needs a great boon. The increasing emphasis on environment has made the waste disposal an important issue and even the closed loop supply chains (Kumar and Yamaoka, 2007) are enforced in many countries. The output subsystem may thus be characterized by the distributor locations, their information resources, mechanism for obtaining feedback from customers and the method of waste disposal and the goodwill in the market.

Total supply chain system

Five subsystems as identified above constitute the total supply chain system. The tasks for each subsystem and the sub-subsystem have been compiled in the tree diagram at total supply chain system level in Figure 5.1. It may be observed that the management subsystem has been further decomposed to reflect all the smaller activities at the lower levels. Similar decomposition to lower levels may be carried for other subsystems also to comprehensively model the total supply chain system. In this chapter, the objective is to demonstrate the methodology and thus the analysis is limited to "level 1" decomposition only.

5.4. Interactions in the subsystems of the supply chain system

The subsystems are interrelated and interdependent on each other in many ways for example, decisions made in finance affect the functioning of operations, purchase and maintenance. Similarly, the quality of work done by maintenance shall have an impact on the timeliness of the operations to complete the order. Sales and distribution has to depend in many ways on operations. Operations have to depend on the purchase, the suppliers and the vendors, etc.

Even though the tree diagram in Figure 5.1 developed above represents all the subsystems of the supply chain system, it fails to include the connectivity and interdependences between different subsystems. So, a schematic diagram is developed as in Figure 5.2 to take care of this deficiency. It is a representative diagram to develop and explain the novel methodology and is not claimed as exhaustive.

This diagram shows all such interactions and is in good accordance with recent findings about the interrelationship between processes, people and management and other subsystems in the most successful companies. Some of the features of this diagram are discussed in the following paragraphs.

The inputs have direct influence over the supply chain process subsystem as the supplier quality (material of inferior quality) or reliability (appropriate quantity and quality material received in time) helps in the smooth running of the operations of supply chain processes.

The output subsystem is directly dependent upon the supply chain process subsystem for in time supply of finished products of suitable quality and reliability, whereas the outputs directly do not affect the supply chain process. Rather, the outputs influence the supply chain process subsystem via a loop through information processing function in the support subsystem and then to the management and control subsystem in terms of providing processed information.

The management subsystem takes control decisions for the supply chain process and finally the supply chain process satisfies the new output requirements, thus completing the loop of information flow. For example, the management subsystem controls the inputs subsystem through activities such as calling for major design changes or the vendor selections. Also, it controls the support subsystem through policy statements for general operation of maintenance and other sub-subsystems besides controlling the supply chain process. There is link from outputs to the management as the management takes feedback directly from the customers as well as distributors so as to formulate various policies being aware of the current situation of the system.

The routine sales-related information and other such raw data collected from different sales outlets as well as from other subsystems such as supply chain process is collected and processed by the support function of information processing and this processed information is then provided to the management subsystem. Therefore, the links exist from outputs to the support system and then to the management system which again can control production planning control system and thus control the supply chain process subsystem and finally the desired output is reached via these interactions.

The loops of interactions represent the most usual function of the management of obtaining feedback and then controlling the supply chain process to produce better products for the output subsystem via various means and procedures. Similarly, the support subsystem assist the supply chain process subsystem by providing useful processed information such as the schedules received from the management subsystem for carrying out various tasks and disseminates information to supplier for arranging the necessary materials depending upon the requirements. The management and control subsystem also obtain performance reports about various elements of supply chain process subsystem (such as humans, equipments, etc.) as well as from other subsystems of input and support. These findings show that the overall functioning of the supply chain system is dependent on its structural design.

The practices followed in the operation of subsystems and in the interactions between these subsystems, distinguish one supply chain enterprise from the other and the authors consider that it is the cause for their success or failure.

5.5. Graph theoretic model of the supply chain system

Though, the schematic diagram of Figure 5.2 is a good representation of the supply chain system structure, along with the interactions and interdependencies between the subsystems of the supply chain system, it is not a mathematical entity. There are a good number of applications of systems models using graph theory (Deo, 2000 and West.D ,2009) and such models have a strong mathematical background. Some of the applications include the systems model for power plants (Mohan et al., 2008), composites materials (Durai Prabhakaran et al., 2006), etc. Xu et al. (2002) have applied graph theory in gene expression data clustering. Thus, for the modeling of the supply chain system, it is quite logical to select the graph theory and matrix algebra .For this purpose, a linear graph, G has been defined as a function of vertex set and edge set as G = f (V,E), where V corresponds to a set of vertices

$V = \{V_1; V_2; \ldots\ V_n\}$ and E corresponds to a set of edges $E = \{e_{12}; e_{23}; \ldots ; emn\}$

Joining different vertices (Deo, 2000 and West.D, 2009).

In the case of the supply chain system, let vertices correspond to subsystems (S_i) and the edges (e_{ij}) correspond to connectivity/interaction/interdependence from subsystem S_j to subsystem S_j. The graph for the supply chain system will be a directed graph as the edge direction is specific to the interactions. So, edge connecting same two subsystems and directed in opposite directions represent a different interaction ($e_{ij} – e_{ji}$). The supply chain system graph has been developed as in Figure 5.3.

The supply chain system graph is a useful mathematical entity and is highly useful for comprehensive understanding of total supply chain system through for visual analysis. But, for computational analysis, the necessary information cannot be stored in a computer directly. For achieving this objective, the supply chain system graph can be represented in the form of various matrices and related models as described in the next section.

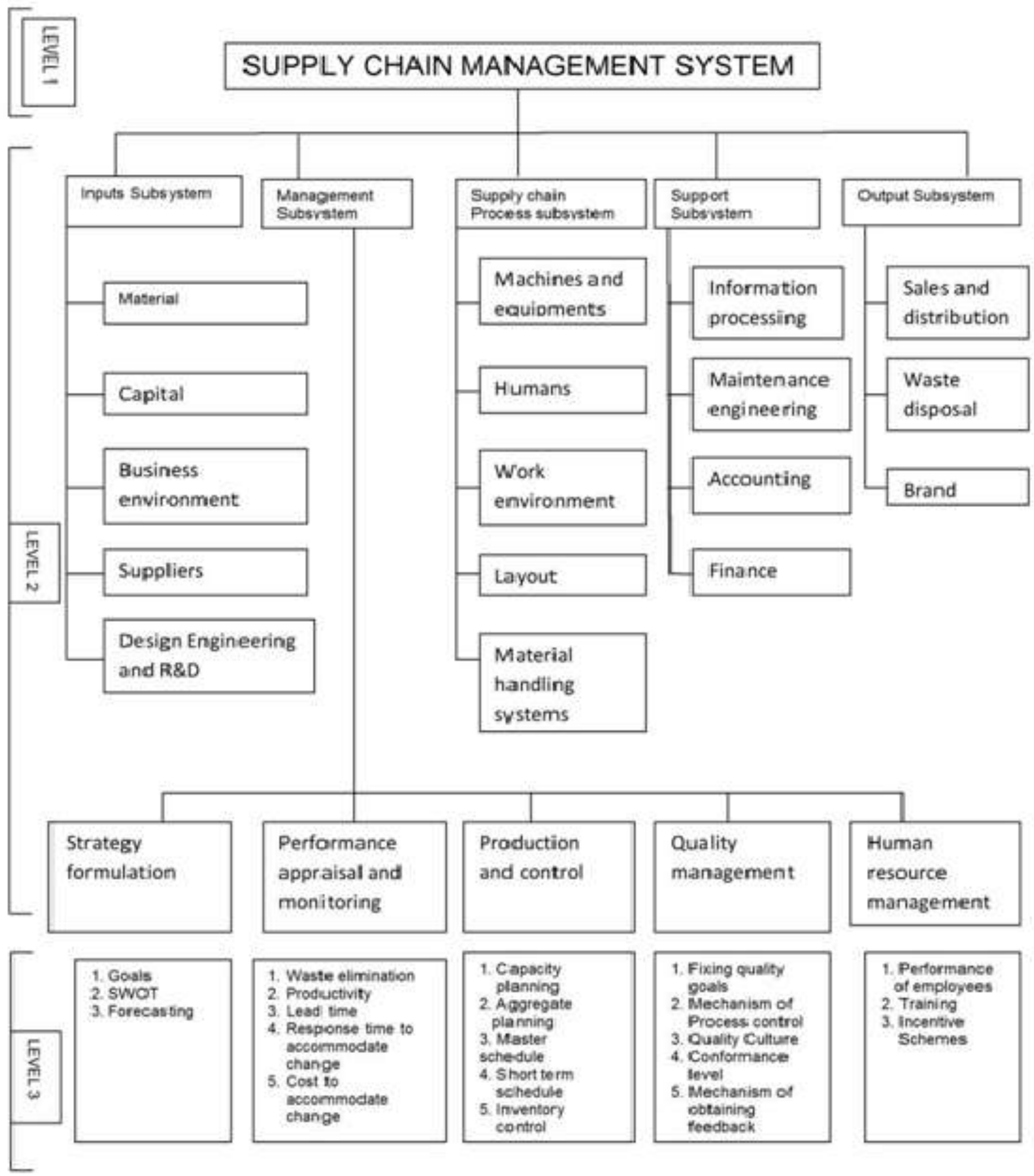

Fig 5.1. Supply chain system tree diagram

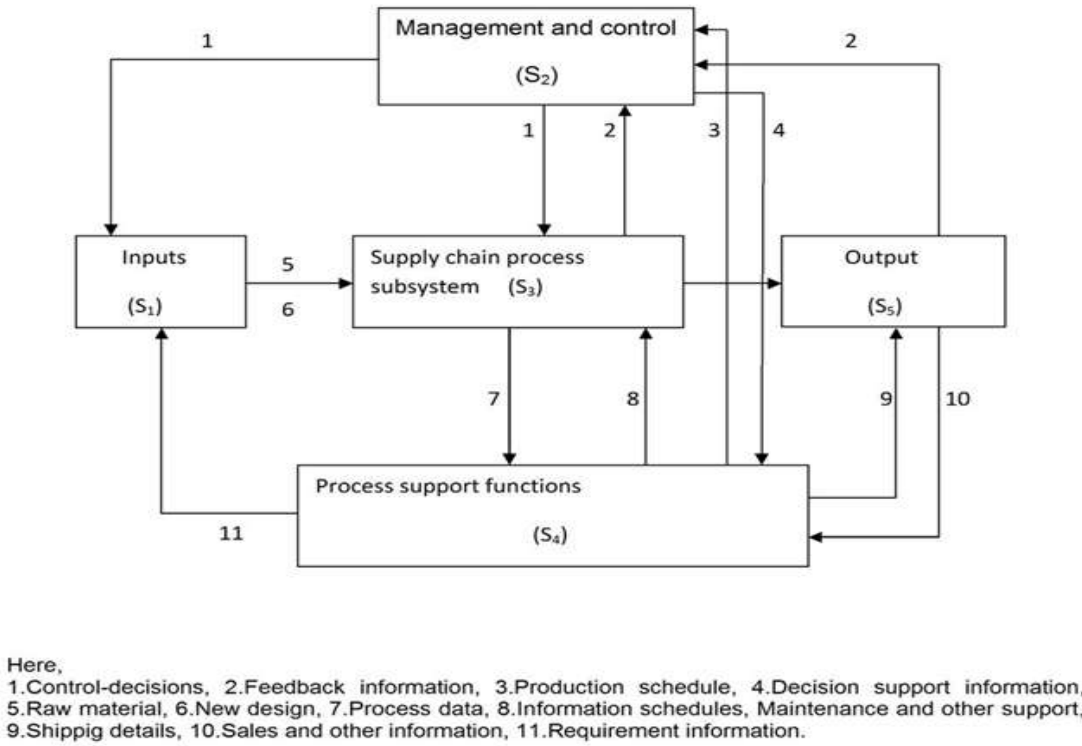

Fig.5.2:-Schematic diagram of supply chain

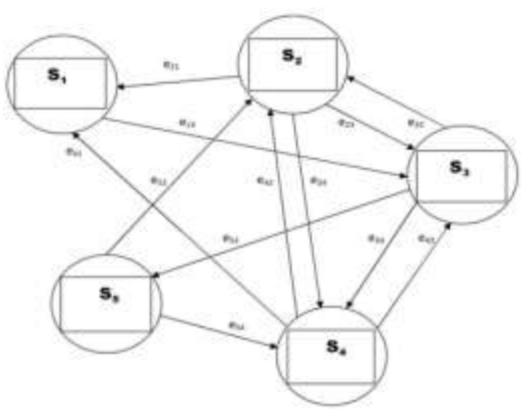

Fig. 5.3 :- Structural graph of supply chain

5.6. Composite performance index and the permanent function

A composite score of the supply chain system in a performance dimension may serve as an important aid in the total performance analysis and one of the ways to obtain it may be by using appropriate numerical values for the supply chain system variables. But in such a case, some structural information of the supply chain system is likely to be deleted because of many subtraction operations. To overcome this limitation, the use of permanent matrix and the permanent function is proposed.

The supply chain system permanent matrix

The permanent matrix is obtained when the negative sign from all the elements in SCSSCIVM(Supply chain subsystem characteristic and interdependence variable permanent matrix) in are converted into the positive ones. The permanent matrix thus developed is named as supply chain system characteristic and interdependence variable permanent matrix (SCSCIVM) and is shown below as matrix P:

$$P = \begin{bmatrix} S1 & 0 & e13 & 0 & 0 \\ e21 & S2 & e23 & e24 & e25 \\ 0 & e32 & S3 & e34 & e35 \\ e41 & e42 & e43 & S4 & e45 \\ 0 & e52 & 0 & e54 & S5 \end{bmatrix} \quad (1)$$

Supply chain system characteristic and interdependence variable permanent function the permanent function of the matrix P in equation (1) has been developed in equation (2). The permanent function, Per (P), differ with the multinomial, Det(C) only in the signs of some of the terms. Number and the type of terms in the two multinomials are exactly the same. Procedure for deriving Det(C) and Per (P) from the respective matrices are identical except no negative signs appearing in Per (P) at any stage of its calculation. Thus, permanent function model is a unique and complete structural representation of the supply chain system with the added advantage of using numerical values of each term without any chance of losing important informatiojn in the total numerical index:

Per (P) = $S_1S_2S_3S_4S_5 + [\, S_1S_2S_3L_{45} + S_1S_2S_5L_{34} + S_1S_3S_5L_{24} + S_1S_4S_5L_{23} + S_1S_2L_{354} + S_1S_5L_{243} + S_1S_5L_{243} + S_1S_5L_{234} + S_4S_5L_{132} + S_1S_3L_{245} + S_2S_5L_{134} \,] + [\, S_1L_{2354} + S_1L_{2345} + S_1L_{2435} + S_5L_{1342} + S_4L_{1352} + S_2 L_{1354} + S_5L_{1324} \,] + [\, L_{13542} + L_{13452} + L_{13524} \,]$

(2)

The numerical index developed based on the permanent multinomial terms in equation (2), by giving numerical value to individual structural elements can be considered a composite score of the total supply chain system in any performance dimension depending upon the one selected for giving values to individual structural elements. This score can prove as a powerful tool for comparison, ranking of different supply chain system designs and optimum selection of supply chain system structure. Thus, the permanent function is proposed as a complete tool for the total structural analysis of the supply chain system.

5.7. Assigning the numerical values

The people working in a particular area of supply chain system tend to understand the supply chain system behavior closely and may be in a position to draw useful and meaningful insights. The numerical values to various subsystems as well as the interactions therein may be assigned by these people depending on the levels of performance in the dimension chosen for analysis. For example, the dimension may be efficiency, reliability, reconfigurability or effectiveness. Thus, a mechanism is formulated to systematically use and combine the knowledge of various experts in a single numerical score. For complex subsystems, the numerical values may be assigned by decomposing the subsystem into further lower comprehensive units and their permanent function may be used as the numerical score for the subsystem. Thus, the numerical values for each subsystem variables S_1, S_2, S_3, S_4 and S_5 may be obtained as below:

S_1=Per(P_{s1}), S_2=Per(P_{s2}), S_3=Per(P_{s3}), S_4=Per(P_{s4}) and S_5=Per(P_{s5})

Where PS_1, PS_2, PS_3, PS_4, PS_5 are the variable permanent matrices for five subsystems.

Thus, the methodology can be applied in a bottom-up approach where in the analysis is proceeded from the lowest level to the total supply chain system level and gives the complete structural evaluation of the supply chain system as a single index.

5.8. Structural analysis of supply chain system

Various terms of the permanent multinomial in equation (2) consist of the structural elements such as subsystem characteristics (Si’s) and structural interactions (eij’s). The existence of elements such as eijeji, eijejkeki, eijejkekleli, eijejkeklelm, emi in the multinomial terms correspond to the subsystems interacting in the form of a dyad, three subsystem, four subsystem and five subsystem loops. These terms correspond to the real subsets of the supply chain system structure. The terms in each group of the multinomial form a separate set, which may be used for characterizing the supply chain system uniquely. These real subsets of the total supply chain system identified from equation (2) may be represented as sub graphs as in Figure 5.4.

It can also be used for designing new SCM or improving over existing/sick systems of a SCM or to improve efficiency of a SCM . Various possible combinations of a SCM and it’s subsystems have been shown in the permanent function. Examples have been shown on how the goals of an individual supply chain can be achieved by the permanent function.

These sub graphs represent the subsystems of the supply chain systems interacting in various ways and thus contributing towards varied goals of the supply chain system.

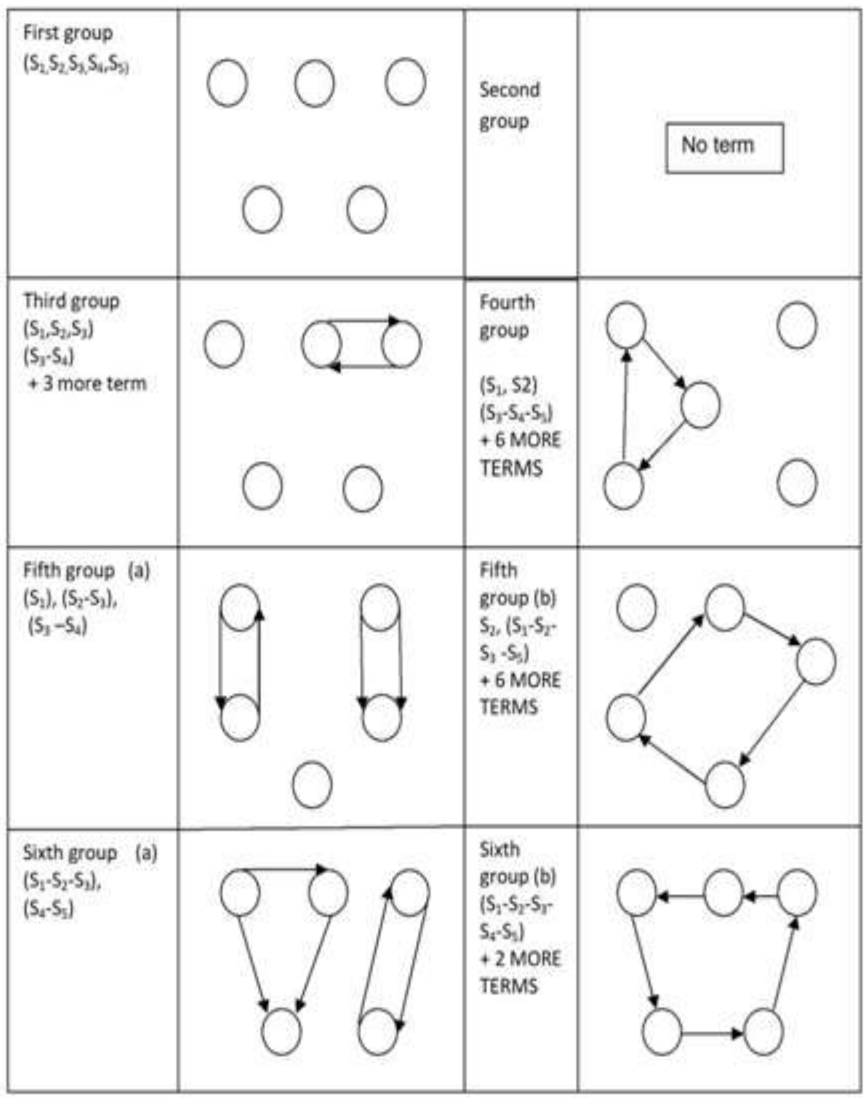

Fig 5.4:- Graphical representation of the permanent multinomial

Example 1

The term (S_1 L_{5423}) of second subgroup of fifth group in the characteristic polynomial may be interpreted as that corresponding to the goal of the supply chain system in the direction of providing defect free and high quality and reliability products to its customers with the use of continuous improvement philosophy. For example, automobile supply chain units when start supply chain a new model may initially are not able to supply automobiles with desired quality and reliability. For achieving the desired levels of quality and reliability, it has to adopt a continuous improvement philosophy along with ensuring the quality of the inputs. A feedback mechanism has to be developed so that the feedback information obtained from the output subsystem may be processed into decision-support information and this processed information is supplied to the management subsystem. The management subsystem directs the supply chain process subsystem for taking corrective action. The supply chain process subsystem may take the corrective action to improve the process and finally be able to supply the products of desired quality and reliability to the outputs subsystem.

Example 2

Also, the fourth group term (S_1 S_2 L_{435}) that has been shown in the diagrammatic representation (Figure 5.4) is representing the measure describing the accomplishment of the schedule. It has a set of two distinct subsystem variables viz. input and management subsystems and the other set of subsystems as a loop of three subsystems viz. supply chain process, support and output subsystems. The element e_{43} as a part of the loop appears in this term because the efficiency of the supply chain process subsystem (S_3) is dependent upon the level of service provided by the support subsystem (S_4). The output subsystem (S_5)

consisting of the distributors and other elements is directly dependent upon the supply chain process subsystem (S_3) through edge (e_{35}) for catering to the needs of the supply chain at appropriate time, which is also called promptness in fulfilling the order of the customer and is a very important dimension that influence the customer and establish a brand image. The support subsystem (S_4) is in turn dependent upon the product requirement from the output subsystem (S_5). The management (S_2) and the inputs (S_1) are contributing to the accomplishment of the schedule in an independent and coherent manner by facilitating and controlling the subsystems that are directly involved in the final goal. Similarly, physical significance of various other terms of the permanent multinomial may be derived and with this approach, the total structural analysis may be carried out by taking into consideration all the possible structural tests which are 24 in number for the supply chain system under consideration based on the terms of the characteristic multinomial.

5.9. Identification and comparison of supply chain system structure

For the given supply chain system, the 24 terms of the permanent multinomial identify all possible structural patterns contributing towards varying goals of the supply chain system and serve as 24 structural tests that may be used to analyze the total supply chain system in 24 distinct ways. So, a systematic technique for the structural identification and comparison of the supply chain systems is developed. The characteristic features of all the six groups of structural members of the supply chain system as identified in equation (2) are summarized as below:

(1) The first group consists of a single term representing a set of five subsystems singularly representing each subsystem. The identification set is $S_1/S_2/S_3/S_4/S_5$.

(2) The second group terms if exist should have four singular subsystems and a subsystem dependent on itself. Such condition is non-existent in the supply chain system and thus the second group is found to be absent.

(3) The third group has four terms, each term a set of three singular subsystems and a "two subsystem loop" or a dyad. The identification set may be written as $S_i/S_j/S_k/S_{lm}$.

(4) The fourth group has seven terms consisting of a set of two singular subsystems and a three subsystem loop. The identification set is $S_i/S_j/S_k/S_{klm}$.

(5) The fifth group consists of two subgroups of one and seven terms, each having one singular subsystem and the first subgroup has two "two subsystem dyads and the second subgroup has a set of one 'four subsystem loop.'" The corresponding identification sets are $S_i/S_j/S_k/S_{lm}$ and $S_i/S_j/S_k/S_{klm}$, respectively.

(6) Similarly, the sixth group has two subgroups and the first subgroup has one term having a set of dyad and three subsystem loop and the second subgroup has three terms, each having a set of five subsystem loop. Similarly, the identification sets may be written as S_{ij}/S_{klm} and S_{ijklm}.

So, from the terms of the permanent or the characteristic multinomial, the identification set for any supply chain system may be written as:

$$/J_1/J_2/J_3/J_4/J_{51}/J_2/J_{61}/J_{62}/, \qquad (3)$$

Where J_k represent the total number of terms in the kth grouping and J_{kl} represent the total number of terms in the lth sub grouping of the kth group.

5.10. Comparison of the supply chain system structure

Comparison of one supply chain system structure with the other alternatives becomes necessary in the wake of rising competition. The competitiveness has long been considered a function of the resources as well as practices followed in various structural components of the supply chain system and most importantly the interactions. All these attributes are represented in the supply chain system structure. Thus, the terms of the permanent function, which represent real subsets of the supply chain system, can be used to compare different alternative choices for the supply chain system structure. This structure-based comparison will also aid in the process of developing new design of supply chain system, business process restructuring and for benchmarking, which have become essential in the modern era (Jafari et al., 2007). The coefficient of similarity and dissimilarity give a systematic method of comparison of the supply chain system structure.

If the number of distinct terms in the lth sub grouping of the kth grouping of the permanent function of the two supply chain systems under consideration be denoted by J_{kl} and J'_{kl} , respectively, the coefficient of dissimilarity and similarity may be defined by two criteria namely criterion 1 and 2 as given below.

Criterion 1. If the difference of the number of terms of the jth subgroup of and ith group of the permanent multinomial, $\phi_{kl} = [J_{kl} - J'_{kl}]$:

$C_{d-1}=1/y_1(\Sigma_k\Sigma_l\phi_{kl})$ (4)

$y_1=\max[\Sigma_k\Sigma_l J_{kl} \text{and} \Sigma_k\Sigma_l J'_{kl}]$ (5)

$\phi= [J_{kl}-J'_{kl}]$

J_{kl}andJ'_{kl} is the no. of distinct terms in the l^{th} sub group of the k^{th} group of the permanent function.

Though the criterion 1 developed above present relatively simple method of quantifying the structural difference between the supply chain systems but this may cause loss of comparison information in the coefficient of dissimilarity.

This is because of the fact that the value of Φkl may be negative also depending upon the structural difference in the supply chain systems under consideration. As a result, the subtraction operations may be involved and may cause limitation in the coefficient of similarity

So, a better criterion y using the squares of the comparison values,ϕ_{kl} is developed in equation (5).

*Criterion 2.*The coefficient of dissimilarity by this criterion is given as:

$C_{d-2} = [1/y_2 (\Sigma_k\Sigma_l\phi_{kl})]^{1/2}$

$y_2=\max [\Sigma_k\Sigma l\ (Jkl)^2 \text{ and } \Sigma_k\Sigma l(J'kl)^2]$

$\phi= [J_{kl}-J'_{kl}]$

As can be easily observed from the structure of the equation the value for the coefficient of dissimilarity will lie between 0 and 1, the coefficient of similarity can be calculated as :

$$C_{s-1}=1 - C_{d-1}, \qquad (6)$$

$$C_{s-2}= 1 - C_{d-2} \qquad (7)$$

where C_{s-1} and C_{s-2} are the coefficient of similarity of two different supply chain systems under consideration by criteria 1 and 2, respectively. The value of one, for the coefficient of similarity indicates that the two supply chain system structures are completely similar. Structural similarity or dissimilarity may be indirectly, a measure of the performance's similarity/dissimilarity as has been already observed from the fact that the different terms of the permanent multinomial being real subsets of supply chain system contributing towards different goals. So, differences or similarities in these terms reflect the shift in supply chain system's capacity in contributing towards these varied goals. The total comparison may be carried out based on the characteristic values for different subsystems. As all the characteristic values and interaction levels are incorporated in the permanent function of the supply chain system, the numerical values as assigned by experts to all these terms will result in single composite numerical score of the total supply chain system. This also forms a basis for classifying supply chain systems based on their structure by comparing it with a benchmarked supply chain system.

5.11. Example of structural comparison

For illustration of the methodology for total structural analysis based on its structure, another supply chain system with a graph as shown in Figure 5.5 and here on called supply chain system B is considered. The supply chain system having its graph in Figure 5.3 be called supply chain system A. In the supply chain system corresponding to Figure 5.5, the direct feedback link from the supply chain process subsystem to the management subsystem is missing. The identification set for this supply chain system A by graph theoretic methodology is written as below as:

$/J_1/J_2/J_3/J_4/J_{51}/J_{52}/J_{61}/J_{62}/ = /1/0/4/7/1/7/1/3/.$

The identification set for the supply chain system B by the graph theoretic methodology is written as below:$/J_1/J_2/J_3/J_4/J_{51}/J_{52}/J_{61}/J_{62}/= /1/0/3/5/0/6/0/3/.$

The change in the structure of the supply chain system may be ascertained in a quantified manner from the coefficient of similarity and dissimilarity. The values of the coefficient of similarity and dissimilarity based on structure by criteria 1 and 2 are written below:

$C_{d-1} = 0.25$, $C_{s-1} = 0.75$

$C_{d-2} = 0.2530$, $C_{s-2} = 0.747$

It is observed that the values are almost the same by both the criteria. This is because of the fact that the term Φkl remains positive. If some terms are present in second supply chain system and while missing in one and some other terms are missing in the second while present in first shall result in inaccuracy in coefficient of similarity by criterion 1. The advantage which makes criterion 1 still usable is its simplicity.

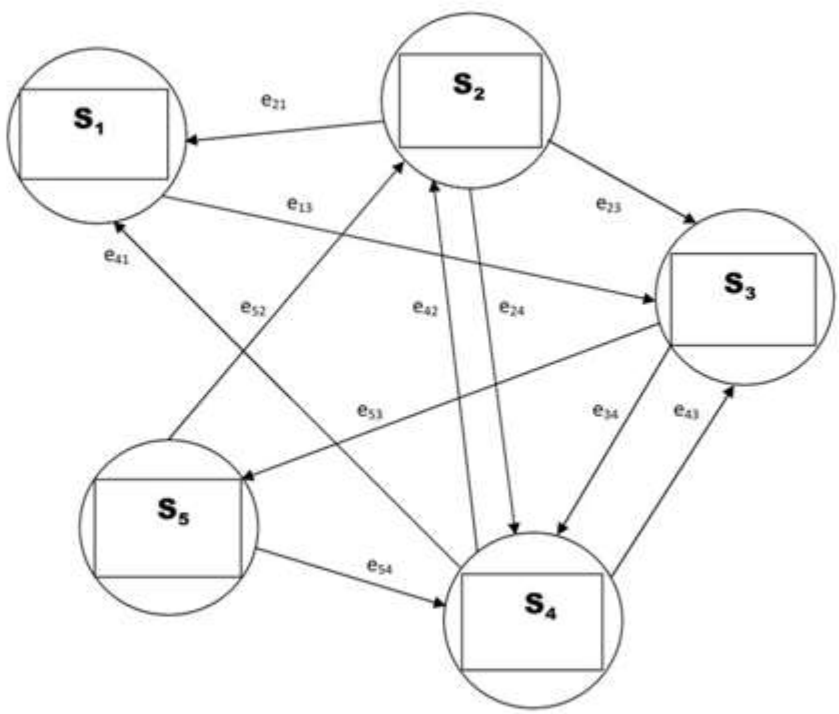

Fig 5.5 Structure of a supply chain with a missing link from (S_2-S_3)

5.12. Various managerial issues in supply chain which can be solved/worked upon by the help of generated model:-

There are various issues like increasing performance, decision making, inter functional co-ordination, supplier integration, deliverability, reliability etc. Which are to be worked upon for efficient management of supply chain. In the following example the use of generated model for making performance measurement and benchmarking decisions, outsourcing decisions in a supply chain management system will be illustrated.

Performance measurement

Performance evaluation assessment system directly affect the target performance level of business operations and development, a good measurement system to ensure that the enterprise's short-term objectives and long-term goals.

a) Performance measurement principle

In order to reflect the operations of the supply chain, there should be set up with suitable methods of supply chain performance measurement and to determine the appropriate target system for performance measurement. Measurement of supply chain performance indicators not only reflect the operating performance of the enterprise, but also evaluate the overall operation of the supply chain performance levels. In actual operation, in order to set up an effective supply chain performance measurement target system, the following principles to be followed:(Nie 2004, 66)

1) Analysis focus on key performance indicators

2) Should use the target system performance which reflect the supply chain business process

3) Measurement indication should be able to reflect the operation of the whole supply chain, rather than just reflect a single node in the operations of enterprises

4) Should maximize the use of real-time analysis and evaluation methods, performance metrics should be extended to reflect the supply-chain information in real –time operation , because this analysis is more valuable than after the work

5) When measure the performance of the supply chain, it is necessary to use the measurement indication, which reflect the relationship of suppliers, manufacturers and users, extend the measurement objects up to relevant enterprise in supply chain

The three objectives for developing and implementing performance measurement systems include monitoring, controlling, and directing logistics operations. Monitoring measures track historical logistics system performance for reporting to management and customer. Controlling measures track ongoing performance and are used to refine a logistics process in order to bring it into compliance when it exceeds control standards. Directing measures are design to motivate personnel (Donald & David 1996, 670).

b) Performance measurement bound

In general, there are three aspects should be considered in supply chain performance measurement: Firstly, internal performance measurement; secondly, external performance measurement; integrated supply chain performance measurement is the third one.

1) Internal performance measurement

Internal performance measure of the supply chain is mainly on the evaluation of the performance of the enterprise. There is a common target: Costs, customer service, productivity, good management, quality and so on.

2) External performance measurement

External performance measurement is the evaluation of enterprises on the supply chain operation. The key indications of external performance are: customer satisfaction, benchmarking of best implementation.

3) Integrated supply chain performance measurement

General supply chain performance measurement aspects includes: customer satisfaction, time, cost, asset and etc.

5.13. PERMANENT MATRIX FOR INTERNAL PERFORMANCE MEASUREMENT:-

$$G = \begin{bmatrix} S1 & e12 & e13 & e14 & \dots. & e1n \\ e21 & S2 & e21 & e24 & \dots. & e2n \\ e31 & e32 & S3 & e34 & \dots. & e3n \\ \dots. & \dots. & \dots. & \dots. & \dots. & \dots. \\ eN1 & eN2 & eN3 & eN4 & \dots. & SN \end{bmatrix} \qquad (8)$$

$$\text{Per(P)} = \begin{bmatrix} S1 & 0 & 0 & e14 \\ 0 & S2 & e23 & e24 \\ 0 & e32 & S3 & e34 \\ e41 & e42 & e43 & S4 \end{bmatrix} \quad (9)$$

Per (P) = $[S_1S_2S_3S_4S_5 + S_1S_2S_3L_{34} + S_1S_3S_4L_{24} + S_1S_4S_3L_{13}] + [S_1S_2L_{123} + S_2S_3L_{134} + S_3S_4 L_{234} + S_1S_3L_{124} + S_1S_4L_{341}] + [S_1L_{234} + S_1L_{234} + S_1L_{243} + S_4L_{134} + S_4L_{132} + S_4L_{241}] + [L_{1342} + L_{1324} + L_{1243}]$

Score's of the permanent function for performance - (for calculating of scores of each system the matrix has been normalized by the given formula)

$n_{ij} = d_{ij} / (\sum_{i=1}^{m} d_{ij}^2)^{1/2}$ column wise normalization

where d_{ij} is an element of the permanent matrix Per(P).

Score of the sub systems are: - (Source for the values is from Tian Ran(2009)for NOKIA-CHINA Dongguang Branch)

Score of the (internal + external) permanent function for performance is 0.69 and is good rated but for the support sub system the score is very low (0.28) which indicates that the performance of the subsystem is not good and should be improved and for improving it we can use benchmarking and which is achieved by the generated model as shown below:-

As the performance index of support sub-system is very poor as indicated by the permanent function value we would like to improve on the available conditions or benchmark a successful support sub-system for making this decision we will calculate the permanent function value for each of the available options and would prefer a highest rated option to be included in the existing system so as to increase the performance index of the supply chain system.

Similarly various other issues of supply chain management can be solved by using this methodology.

SUB-SYSTEM	SCORE
1) Input subsystem	0.78
2) Management subsystem	0.82
3) Supply chain process subsystem	0.79
4) Support subsystem	0.28
5) Output subsystem	0.76

Table.(5.1) showing scores of the sub-systems of the supply chain system Tian Ran(2009)

5.14. Generalization of the permanent function model

For a general supply chain system with N subsystems, the supply chain system characteristic and interdependence permanent matrix, G may be written as in equation (10) below:

$$G = \begin{bmatrix} S1 & e12 & e13 & e14 & \dots. & e1n \\ e21 & S2 & e21 & e24 & \dots. & e2n \\ e31 & e32 & S3 & e34 & \dots. & e3n \\ \dots. & \dots. & \dots. & \dots. & \dots. & \dots. \\ eN1 & eN2 & eN3 & eN4 & \dots. & SN \end{bmatrix} \qquad (10)$$

For a general N subsystem supply chain system with all the subsystems linked together, the total number of terms of the permanent function shall be equal to N! For a five subsystem graph with all possible interconnections present, there will be 5!, i.e. 120 number of terms for the permanent multinomial.

5.15. Usefulness of the methodology

The methodology is based on a flexible and comprehensive model of the supply chain system, which can consider all the subsystems as well as the interactions between them. Thus, it gives a method of analyzing the total supply chain system in an integrated way. A comparison of the proposed graph theoretic models with several others models of supply chain system has been given below.

Comparison of the proposed methodology with other models of supply chain systems

Some of the frameworks for modeling supply chain systems are Holonic supply chain systems approach, Bionic supply chain system and the fractal factory concept. Ryu and Jung (2008) have proposed agent-based models for dynamic situations. All these above concepts call for a new organization structure for supply chain systems in which there are number of distributed and autonomous units operating as a set of coordinating entities. Though the models of these types are highly suitable for dynamic market conditions, the systematic integration remain a major concern. Sheu and Laughlin (2006) had also made an attempt to address the issue of integration in supply chain systems, but the concept is limited to integrate only marketing with supply chain. Zutshi and Sohal (2005) have shown the results of integration of management system for quality, occupational health and safety and the environment. Lee et al. (2005) have also developed an object-based knowledge integration system for early stages of product development. The model has dynamic information exchange capability. Alexopoulos et al. (2007) have proposed a new direction for supply chain system modeling as an oscillator analogy. Hsu and Sha (2007) have used simulation-based models to have integrated analysis which cannot make use of the up-to-date knowledge of the human resources. Also, in all models discussed above, the quantification for the interactions is not addressed appropriately. Petrinet-based model (Zimmermann and Hommel, 2009) for design and performance evaluation of the supply chain system is a useful contribution for addressing integration issues. Under this model, different model parts are merged to create a complete model of the supply chain system. The only limitation is that it needs a large library of model templates. Graph theoretic-based analysis is a unique methodology, which is flexible to expand the analysis, can be quickly built based on simple logic, is mathematical in nature and integrates the analysis over the total supply chain system. Graph theoretic model may be used to analyze such situations, which are emerging from the globalised market situations, in a more comprehensive way. Usefulness of the proposed model is highlighted by giving a list of suggested application areas.

5.16. Suggested applications of the methodology

The methodology will prove to be very useful for the supply chain industry in various ways as listed below:

1. The permanent multinomial terms can lead to a unique method of characterization and codification of the supply chain systems. This will assist in the selecting compatible set of supply chain practices (Ungan, 2007). Also, different alternative structures may be co compared, ranked and thus optimally selected. The structural analysis may aid in reviving certain non performing industrial units or some of the divisions therein. The methodology may be applied for problem identification and its various causes. The downsizing as measure to boost productivity may be profitably carried out through identification of redundant elements in the supply chain system. Business process reengineering (BPR) can be carried out making use of this methodology.

2. The numerical values in the permanent multinomial may yield a composite score of the total supply chain system in various performance areas such as flexibility, reliability, etc. It may act as a powerful tool in comparing, ranking and selecting appropriate design from various alternatives available based on various performance measures.

3. The composite index of the supply chain system performance may be used for comparing the supply chain systems with the best ones in the industry, thus acting as a vital aid in the research area of benchmarking.

4. The coefficient of similarity as well as dissimilarity developed may act as another useful analytical tool for comparison of different structural designs of supply chain systems.

5. All important subsystems which are missing in the current methods of supply chain system modeling (Chang et al., 2005; Oakland and Oakland, 2008) may be directly incorporated in the analysis, for example humans, environment, etc.

6. The limitation of lack of visibility (Blackhurst et al., 2005) on other portions of the supply chain system can be overcome by this model as it considers all structural elements of the supply chain system in totality.

7. The model can generate different "what if" scenarios, which can act as a decision-support tool before the complex, time consuming and capital intensive decisions are made.

8. The tool can support the concurrent engineering concept in supply chain system, by providing means for simultaneous consideration of all aspects of a problem.

9. Using this methodology, computational analysis can be carried out, which will result in a very useful software tool for selecting the optimum parameters for the real-time operation of the supply chain system.

10. By making use of the suggested methodology, supply chain system may achieve the objective of becoming lean (Bhasin and Burcher, 2006), flexible (Boyle, 2006) and agile (Ramesh and Devadasan, 2007) for dealing with the varying situations under which it may have to operate.

5.17. Procedure to develop and use graph theoretic supply chain system structural model

The proposed methodology is written in the form of a step-by-step procedure and can be implemented by any existing industry in its supply chain division which is interested in developing the graph theoretic model to have a comprehensive understanding of the supply chain system so that improvement decision of the subsystems can be analyzed by the use of better technology and the effect may be assessed:-

(1) Development of the vision, mission and goals of the supply chain system.

(2) Identification of the attributes of the supply chain system.

(3) Identification of different subsystems.

(4) Development of block diagram showing different interactions between the subsystems.

(5) Development of different hierarchical tree structures for various subsystems.

(6) Development of graph theoretic models of total system showing subsystems and their interactions.

(7) Development of MSPM.

(8) Development of the permanent multinomial.

(9) Structural analysis through terms of the permanent multinomial.

(10) Alternative structural design concepts can be developed or different decisions can be taken for quality improvement (Kaizen) or reengineering of the supply chain system for breakthrough improvement.

(11) Carry out structural evaluation, comparison, ranking and system wide optimum selection.

(12) Development of decision-support system for various applications.

Algorithm for new design of supply chain system

An algorithm has been given for utilizing the graph model for developing a new design of the supply chain system with desired capabilities in various areas to serve varied goals of the supply chain system:

(1) The desired supply chain system is conceptualized by considering and listing various goals.

(2) Various subsystem attributes as well as the interaction modes may be formulated to reach the desired goals.

(3) The values of different terms of the permanent multinomial, which are real structural subsets of the total supply chain system contributing towards various objectives of the supply chain system is compared with the desired levels.

(4) If the output is not satisfactory, the areas for improvement are identified and necessary modifications in the design may be made.

(5) The coefficient of similarity as well as dissimilarity may be used for comparison of different structural designs of supply chain systems.

(6) Again the Steps 3 and 5 are repeated till the desired design is obtained.

Chapter 6

Selection Of Supply Chain Strategy Based On Risk And Customer Sensitivity Dimensions By Systems Approaches.

6.1. Introduction

Every human endeavor involves risk and the success or failure of any venture depends crucially on how we deal with it (Dey and Ogunlana, 2004). The word risk carries different connotations and is generally associated with finance and terms like options, futures, swaps in context of managing risks are commonly used in today's business parlance. According to Emblemsva°g and Kjølstad (2002) the word "risk" is derived from the early Italian word risicare, which originally meant "to dare." Mitchell (1999) discussed the relationship between objective and subjective risk, and suggested that objective risk must exist in theory. He also concluded that an objective measure of risk is difficult to obtain and all that can be easily measured is the subjective or perceived risk. An effective program of risk management is an ongoing process of assessment, Intervention and fallback planning (McGrew and Bilotta, 2000) and according to Bandyopadhyay et al. (1999) four major components of risk management are:

(1) Risk identification;
(2) Risk analysis; (3) risk-reducing measures; and
(4) Risk monitoring.

In the global economy along with the risks businesses are also faced with customers harder to generalize and thus managing variety and quantity with least cost ramifications is a challenge. Customer sensitivity is a trait which helps the companies to understand better about their customers and the markets which they serve. But there are no quick fix solutions to build customer sensitive supply chains' and supply chain strategists have found it to be one of the most challenging tasks.

Today supply chains are striving to improve upon customer sensitivity dimension by taking advantages of outsourcing and leveraging their partners' capabilities. This endeavor has ramifications in the form of an increase in risk susceptibility as along with their capabilities, partners also bring new risks to the overall supply chain. Thus, organizations have to assess and evolve strategies to manage risks outside their organizational boundaries impacting the overall supply chain. Further contemporary research also recommends that supply chains need to be designed as lean, agile or leagile according to the type of product and the requirements of the markets (Christopher, 2000; Mason-Jones et al., 2000; van-Hoek et al., 2001; Christopher et al., 2004). But a supply chain design based only on the requirements of the markets without sufficient regard to the inherent risks is fraught with high probability of failure. In literature no study was found which considered the impact of risk on the structure of the supply chain. So the major objectives of this chapter can be stated as:

1. To develop a model that maps traditional, lean, agile and leagile supply chains on customer sensitivity and risk alleviation competency dimensions.

2. To evaluate the suggested model for case supply chains by quantifying risk alleviation competency and customer sensitivity dimensions.

6.2. Supply chain risk management

Supply chain management (SCM) involves managing complex flow of information, materials, and money across multiple functional areas both within and among companies. The aim is to achieve goals related to total system performance rather than optimization of a single phase in a supply chain (Helo and Szekely, 2005). Typically the goals for SCM are to develop value-added processes that deliver innovative, high-quality, low-cost products on time with shorter development cycles and greater responsiveness (Fawcett and Magnan, 2004). This necessitates companies to identify, evaluate, rank, and manage its supply chain risks. Company's obsession with speed and costs also causes supply chains to break down particularly during the launch of new products (Lee, 2004). According to Speckman and Davis (2004) as supply chains takes advantage of core competences of partnering firms it should also be prepared to manage the risks that may emanate because of partnering firms practices related to environment and ethics. Successful companies would be those that can identify and develop contingency plans for various risks that exist internally and externally to the organization (Zolkos, 2003). Although at the strategic level supply chain risk management is relatively new and rapidly expanding discipline (Gunasekaran et al.,2004), an appropriate and effective organizational strategy is an imperative to mitigate supply chain risks (Finch, 2004).

The sources of supply chain risks are many, as different links of a supply chain are exposed to different types of risks. Supply chain risks even include risks of sharing sensitive information such as inventory levels and production schedules with other channel members (Rahman, 2004). Dependence on outsourcing, tendency to accept short-term profits (Chandra and Kumar, 2000), pursuit to become more agile and lean adds to the overall risk susceptibility. Generally organizations plan to protect against recurrent, low-impact risks in their supply chains but ignore high-impact, low-likelihood risks (Chopra and Sodhi, 2004). These may range from terrorist attacks (e.g. 7/11in New York or 7/7 in London), natural calamities (Tsunami, floods) or contagious epidemics (SARS, Bird flu). In addition to these, supply chain is also exposed to market risks like seasonality, volatility of fads, new product adoptions, and short product life (Johnson, 2001). All these predictable and unpredictable risks have made organizations to rethink their risk management strategies in context of supply chains serving across nations and continents. Supply chain risk management is to collaborate with partners in a supply chain, apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources (Norrman and Jansson, 2004). Though a firm has limited control over the events that disrupt a supply chain, but it can control how well a supply chain copes with those disruptions (Swaminathan, 2003). Supply chain risk management is important because:

- Focus on core competencies has increased the companies' dependence on outsourcing (for both products and services).
- ICT revolution has eliminated the geographical boundaries for developing supply chain partnerships.
- Disruptions in supply chains due to natural calamities and terrorist attacks have more far reaching impacts. This is because of highly integrated nature of today's supply chains.
- Overemphasis on reduction of supplier base or even opting for single sourcing.

- Volatile nature of economies due to strong linkages with fuel prices.

Traditionally, the easiest way of managing supply chain risk has been through inventory, but shorter product life cycles and fast changing customer needs have made this option very risky in itself. Risk management in a supply chain also requires certain tradeoffs, e.g. dependence on single supplier may be risky but the risks to intellectual property when working with single supplier are far less. As discussed risks cannot be completely eliminated from supply chains but strategies can be developed to manage these risks if the dynamics between the variables related to risks in a supply chain are understood. Some of the variables that would help alleviate risks in a supply chain are shown below.

6.2.1 Information sharing

Information sharing is vital for supply chains as lack of information lead to panic, chaotic behavior and unnecessary costs (Childerhouse et al., 2003). Contemporary models for SCM agree that the sharing of business information is a crucial element, which binds supply chains together from end-to-end (Zhenxin et al., 2001; Yu et al., 2001). Free exchanges of information which starts with the product development stage and continue with the mature and end-of-life phases of the product life cycle has been found to be highly effective in reducing the risks associated with inventories, obsolescence and supplier failure (Lee et al., 1997; Lee, 2002). Advent of internet and e-commerce had provided opportunities to all the participants of a supply chain to transfer the information in real time with least transaction cost and global reach (Zeng and Pathak, 2003) resulting in substantial reduction in coordination and distribution costs (Koh and Nam, 2005).

6.2.2 Collaborative relationships and trust

Modern supply chain literature recommends collaborative relationships to achieve long term competitive advantage (Olorunniwo and Hartfield, 2001; Hsu, 2005). In collaborative arrangements management devotes considerable energy in negotiating equitable arrangements for sharing the burdens and rewards of supply chain improvements (Lockamy and Smith, 2000). So to manage risks successfully in a supply chain, organizations are moving to embrace closer relationships with key suppliers (Giunipero and Eltantawy, 2004) which requires deep reorganization of relationships with partners embedded in the network (Caputo et al., 2004). Today there is an increased emphasis on electronic collaboration facilitated by internet technology which has enhanced cooperation and sharing of resources as well as added value to products and improved partners' profitability (Peng et al., 2005; Cheng et al., 2006). Collaborative relationships require trust and commitment for long-term cooperation along with a willingness to share risks (Sahay and Maini, 2002). Degree of trust among supply chain partners enhances commitment (Mistry, 2005), while lack of trust is cited as one of the major factors that contribute to supply chain risks (Sinha et al., 2004). To consciously reduce mistrust in existing relationships, supply chain managers must continually draw attention to the benefits, which arise due to a certain degree of trust between both parties (Sahay, 2003). Trust is developed through consistent and predictable acts of the partner over an extended period (So and Sculli, 2002) and has an important role to fulfill in the well-functioning of lean, responsive, and agile supply chains (Svensson, 2001).

6.2.3 Aligning incentives and proper revenue sharing arrangements

Generally the goal of every firm is to maximize its own interests, but companies assume, wrongly, that when they do so, they also maximize the supply chains' interests. According to Mentzer et al. (2001) a key component for SCM is sharing both risks and rewards among the members of the supply chain. A supply chain works well if the incentives of its member companies are aligned which requires that the risks, costs, and rewards of doing business are distributed fairly across the network (Narayanan and Raman, 2004). Revenue sharing is a kind of supply chain contract that makes possible to share the risks among supply chain partners (Tsay, 1999). Chauhan and Proth (2004) presented a provider-retailer partnership model based on profit sharing while Giannoccaro and Pontrandolfo (2004), has proposed a model of an SC contract aimed at coordinating a three-stage SC, which is based on the revenue sharing mechanism.

6.2.4 Knowledge about risks and risk analysis

Hallikas et al. (2004) suggested that improved understanding about risks in a supply chain helps to make better decisions and decreases the risks of both a single organization and the whole network. There are many different forms of supply chain risks which can be classified according to how their realization impacts on a business and its environment (Harland et al., 2003). According to Morgan (2004) risk in a supply chain can be sorted in four general categories namely political, economic, terrorism related and "other." By understanding the variety and interconnectedness of supply-chain risks, managers can tailor balanced, effective risk-reduction strategies for their companies (Chopra and Sodhi, 2004). Risk analysis is a practice with methods and tools for identifying risks in a process (Sinha et al., 2004). It provides a disciplined environment for proactive decision making to assess continuously what could go wrong, determine which risks are important to deal with, and implement strategies to deal with those risks (Shtub et al., 1994). To assess supply chain risk exposures, the company must identify not only direct risks to its operations, but also the potential causes or sources of those risks at every significant link along the supply chain (Norrman and Jansson, 2004).

6.3. Customer sensitivity

This attribute is the key differentiator of modern approach from the traditional approach of managing supply chains. Companies like Sony, Whirlpool, Remmele Engineering have worked very hard to become customer sensitive (Meredith and Francis, 2000; van-Hoek et al., 2001; Slone, 2004). In total contrast to the traditional practices where majority of inventory was held as finished goods waiting to be sold, customer sensitive supply chains try to hold majority of stock as work in progress inventory awaiting build/configuration information coming from the final customer. This is because the insight and information gained from customers would help to resolve problems regarding market uncertainty (Hsieh and Chen, 2005) and assist supply chains to respond better to the final customer requirements. Customer sensitivity incorporates demand for individualized products and services with quicker delivery time and fast response to sudden changes in order quantity and specifications. It dictates that collaborative initiatives should be driven by quick response to customer requirements (Yusuf et al., 2004) and requires that the supply chain is capable of reading and responding to real customer demands (Christopher and Towill, 2000). Variables that impact customer sensitivity in a supply chain are:

- Responding to real demand (van-Hoek et al., 2001; Christopher, 2000; Yusuf et al.2004);
- Fast introduction of new products (Lin et al., 2006);
- Retain and grow customer relationships (Lin et al., 2006); and
- Customer-based measures (Christopher et al., 2004).

6.4. Traditional, lean, agile and leagile supply chains

6.4.1 Traditional supply chain

The traditional supply chain is defined as an integrated manufacturing process wherein raw materials are manufactured into final products and then delivered to customers (via distribution, retail, or both). Its design, modeling, and analysis had primarily focused on optimizing the procurement of raw materials from suppliers and the distribution of products to customers (Beamon, 1998, 1999). Traditional supply chain strives to achieve the lowest initial purchase prices while assuring supply. Its typical characteristics are: multiple partners, partner evaluations based on purchase price, cost-based information bases, arms-length negotiations, formal short-term contracts and centralized purchasing (Spekman et al., 1998). All these features lead to forecast inaccuracies and slow response to the changing market scenarios.

6.4.2 Lean supply chain

Leanness means developing a value stream to eliminate all waste, including time, and to enable a level schedule. The origins of lean philosophy can be traced to the Toyota Production System (TPS) (Ohno, 1988) and focuses on the elimination of all waste, including time, to enable a level schedule to be established (Naylor et al., 1999; Mason-Jones et al., 2000). According to Karlsson and Ahlstrom (1997) most of the lean principles are applicable to small and medium enterprises (SMEs) and there exists a close synergy between the lean practices and environmental management (Green et al., 1998).

6.4.3 Agile supply chain

Emergence of a new business era characterized by continuous and unpredictable changes with a focus on core competence and mass customization has forced companies to find flexible ways to meet customer demand (Duclos et al., 2003). Agility is defined as business-wide capability that embraces organizational structures, information systems, logistics processes and, in particular, mindsets (Christopher and Towill, 2000). Agility focuses on maintaining good productivity under pressure of uncertainty (Helo, 2004). The goal in achieving agility is to establish a seamless supply chain in which all "players" think and act as one (Mason-Jones and Towill, 1999). An agile supply chain had been recognized as a competitive strategy for companies to survive and prosper (Xu et al., 2003).

6.4.4 Leagile supply chain

Lately the concept of “leagile” supply chains is proposed by several researchers (Naylor et al., 1999; van-Hoek, 2000; Mason-Jones et al., 2000; Christopher and Towill, 2001). “Leagile” takes the view that a combination of lean and agile approaches be combined at a decoupling point for optimal SCM. Mason-Jones et al. (2000) argued that agility can be used downstream and leanness upstream from the decoupling point in the supply chain. Thus, leagile enables cost effectiveness of the upstream chain and high service levels in a volatile marketplace in the downstream chain. According to Christopher and Towill (2001) if the whole concept of leagility is properly understood, lean and agile businesses can co-exist, even on the same site and with some limited rotation of personnel.

Some suggested methods by which lean and agile paradigms could be combined to provide affordable products within requisite time frames are presented in Table 6.1. Today there is a need to match the supply chain strategy with the product characteristics. Product characteristics implies the nature of the product which may range from commodities to highly customized products like fashion goods. Figure 6.1 tries to suggest suitable supply chain strategy based on product characteristics and supply chain risk alleviation competency. If the nature of the product is commodity and risk alleviation competency is low then the suitable strategy is to opt for lean supply chain. If the product required is highly customized and risk alleviation competency of the supply chain is high then it is most suitable to design supply chain as an agile entity, one which can transform itself according to fast changing customer preferences.

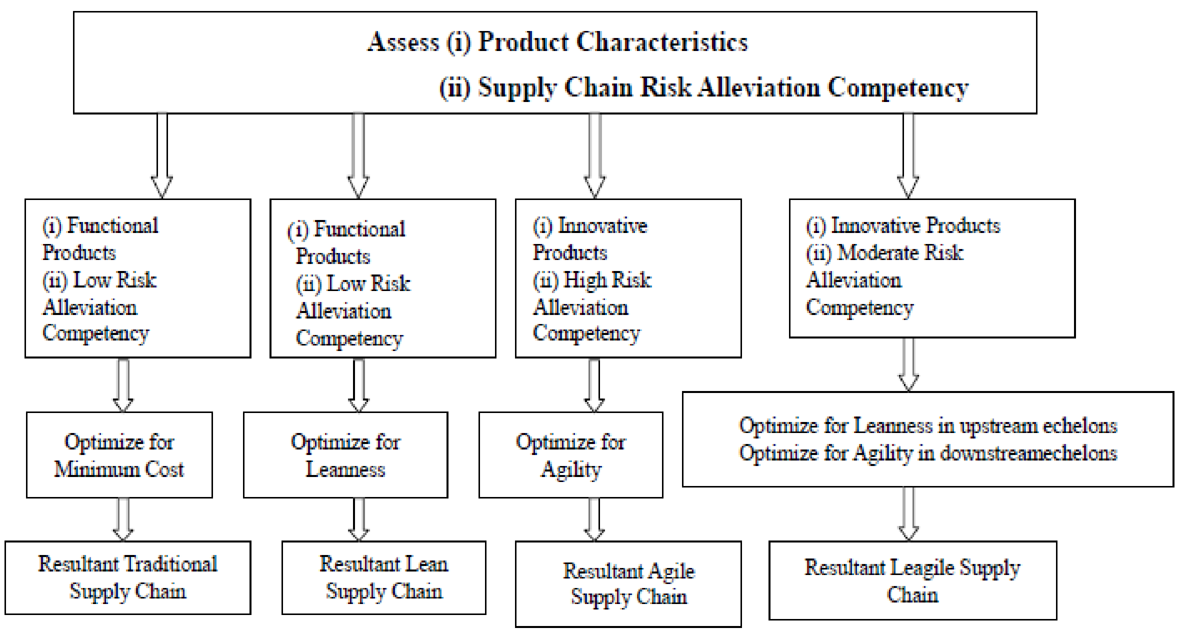

Fig.6.1:- Traditional, lean, agile and leagile supply chains- the linkages (Source Operation’s Management by Chase, R.Shankar and others)

6.5. The model: mapping supply chains on risk alleviation competency and customer sensitivity dimensions

Traditional supply chains does not focus on elimination of waste and so in certain situations particularly in those where the flow of the material or information from one echelon to another is disrupted it can still manage to deliver as here inventory would be a buffer against those sudden disruptions albeit at higher costs. But the biggest drawback of traditional supply chain is that it is highly unresponsive to both demand and variety required in the marketplace. This is because of little information sharing, as the relationships with its suppliers and customers are short-term and cost-based. Further because of the forecast inaccuracies the higher levels of inventories maintained would increase the obsolescence costs. So it ranks poorly on both customer sensitivity and risk alleviation competency dimensions. Christopher (2000) suggested that lean concepts work well where demand is relatively stable and where variety is low with low cost delivery process (Stratton and Warburton, 2003). According to Chopra and Sodhi (2004) in case of lean supply chain bare-bones inventory levels decreases the impact of over-forecasting demand, but simultaneously increases the impact of a supply chain disruption. Also in a quest to become lean, supply chains are more dependent on outsourcing which make them more vulnerable as accidents impacting any link of the supply chain would have an influence on supply chain’s overall performance. Lean concepts assume that the demand is relatively stable and variety demanded by the customer is low. Thus, the supply chain is designed with a focus on waste elimination and little focus on market responsiveness. So when the customer requirements are somewhat stable and risk alleviation competency required is moderate lean supply chain would work well.

An agile supply chain is market sensitive with the ability to respond to actual real time changes in demand (Faisal, 2005) and so it ranks high on customer sensitivity dimension. According to Prater et al. (2001) supply chain agility is determined by speed and flexibility of sourcing, manufacturing and delivery. This is only possible when collaborative relationships exits between the supply chain partners facilitating information sharing and proper revenue sharing arrangements. An agile supply chain also has a high risk alleviation competency value as it can easily reconfigure itself according to the new market environment in very little time. As leagile supply chain combines both lean and agile supply chain paradigms it is necessary that demand remains stable in the upstream side before decoupling point of the supply chain so that lean principles can be applied. After the decoupling point the focus is on agility and so it would respond well to the required market variety. As this supply chain strategy combines lean and agile principles and requires that demand remains stable after decoupling point it has a moderate risk alleviation competency value (Figure 6.2).

6.5.1 Case examples

6.5.1.1 Garment cluster

Tirupur is India’s biggest textile cluster. Post-quota, India would be one of the major beneficiaries in the apparel and textiles. Indian strength lies in availability of low cost raw material as it is one of the biggest producers of cotton and has well-developed spinning and weaving industry coupled with cheap labor costs. To take advantage of the new regime manufacturers have invested heavily in latest machinery and up gradation of existing facilities. They also hired consultants to raise quality standards, implementing enterprise resource planning systems, and training employees to improve productivity. Representatives from Treviso, an Italian cluster of fashion garment manufacturers, Brandix from Sri Lanka, SR Gent from Singapore and assorted firms from Taiwan have come to India looking for manufacturing facilities (Surendar and Rajshekhar, 2004). Managers from Sara Lee visited this cluster and were so impressed that they were ready to approve one of the manufacturers as their approved supplier while another unit bagged a contract to supply garments to Wal Mart (Business Line, 2003).

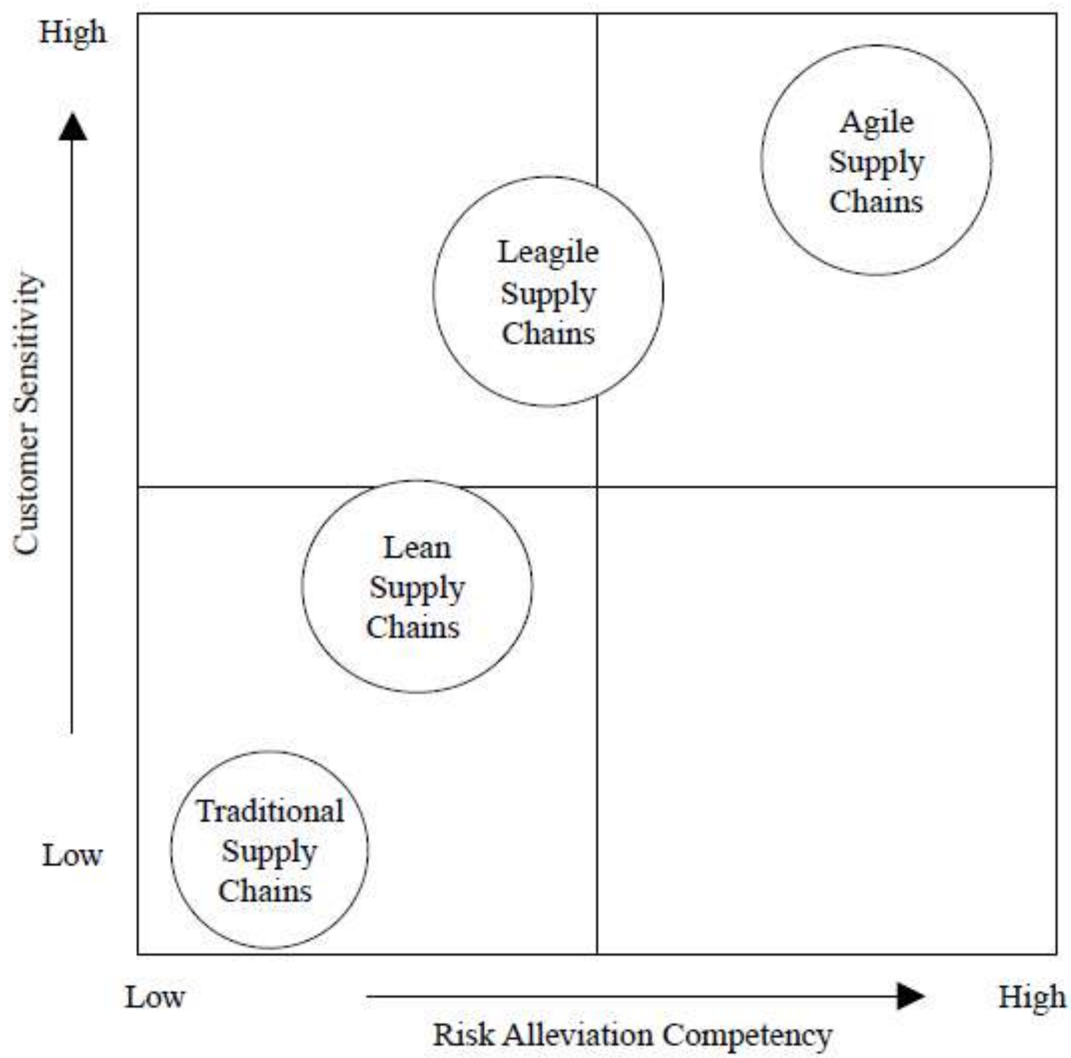

Fig.6.2:- Mapping supply chains on costumer sensitivity and supply chain risk alleviation competency dimensions

6.5.1.2 Machine tool cluster

The machine tool cluster of Bangalore encompasses about 125 firms, including 45 machine tool manufacturers (MTMs) and 70-80 small-scale producers of machine components. The cluster has a turnover of USD 50 million approximately 40 per cent of India's total production of machine tools. However, most of this arises from the domestic sales. SMEs were disorganized and lacked the capacity of collectively addressing their problems the greatest was supply chain linkages to upgrade their products' quality in order to remain competitive in a global market. This need has become more important in view of recession in the domestic market and the mounting competition from foreign producers. In 1999, United Nations Industrial Development Organization (UNIDO) began its assistance to this cluster which has resulted in several improvements like entry into the Chinese market which has a shortage of customized machine tools (Russo, 2003).

6.5.1.3 The leather cluster.

Indian leather industry is a US$4 billion industry generating employment for about 2.5 million out of which 30 per cent are women. Estimated 15 per cent of total purchase of leading global brands in footwear, garments, leather goods and accessories in Europe, is outsourced from India with 100 per cent overseas investment allowed in tanning and footwear. Germany, with a 19 per cent share is the largest buyer of Indian leather products followed by the UK (17 per cent) and the USA (16 per cent). Leather cluster-based at Kanpur manufactures primarily two categories of leather products one consisting of footwear and garments while another of riding accessories. This cluster uses primarily indigenous natural resources with little imports and 75 per cent of the total production of leather and leather goods takes place in SMEs sector with exports accounting for major earnings. This cluster has developed links with its buyer with a lot of emphasis on latest IT tools particularly the internet which has helped it to be more market responsive.

6.5.2 Methodology

For risk alleviation competency and customer sensitivity evaluation of supply chains graph theoretic approach would be applied. By using this approach we can transform the risk alleviation competency and customer sensitivity into single numerical values. This would help to compare and map supply chains on these two dimensions. The use of graph theory is well documented in literature and can be applied to model and analyze various types of systems (Grover et al., 2004; Rao and Gandhi, 2001; Wani and Gandhi, 1999).

The main steps of the methodology are as follows:

(1) Identify the variables for risk alleviation competency and customer sensitivity for the supply chain and in addition, also consider relative interdependencies between those variables. In this case based on literature review we have selected four variables each for risk alleviation competency and customer sensitivity dimensions.

(2) Develop the digraphs for risk alleviation competency and customer sensitivity considering the variables identified for each of them and their interdependencies. The number of nodes must be equal to the number of variables considered in step 1 above. Digraphs for customer sensitivity and risk alleviation competency are shown in Figures 6.3 and 6.4.

(3) Transform the digraphs into matrices as per expression (1). These will be 4 x 4 matrices.

(4) Transform these matrices into permanent functions as per expression (2) and substitute the values of the variables in consultation with experts. In this case the values were selected in a brainstorming session which included two academicians, one with research interests in small business and SCM and two supply chain experts working in Indian SMEs segment. Values ranged on a scale of 1-5 where 1 denotes very weak and 5 denotes very strong.

(5) Obtain single numerical values for risk alleviation competency and for customer sensitivity for the case supply chains as per expression (2). The values obtained are presented in Table 6.2.

(6) Based on the values obtained for customer sensitivity and risk alleviation competency suggest suitable supply chain strategy and also how transition can be made from the current model to lean or agile or leagile based on market requirements.

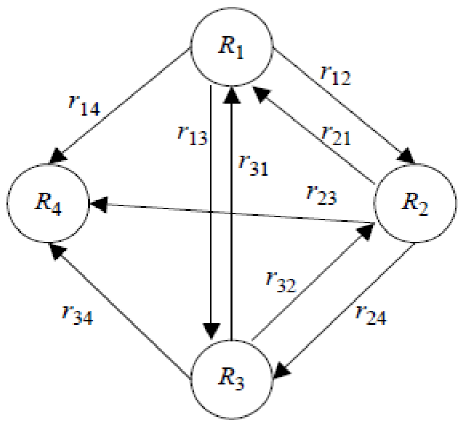

Fig. 6.3:- Risk alleviation variables diagraphs

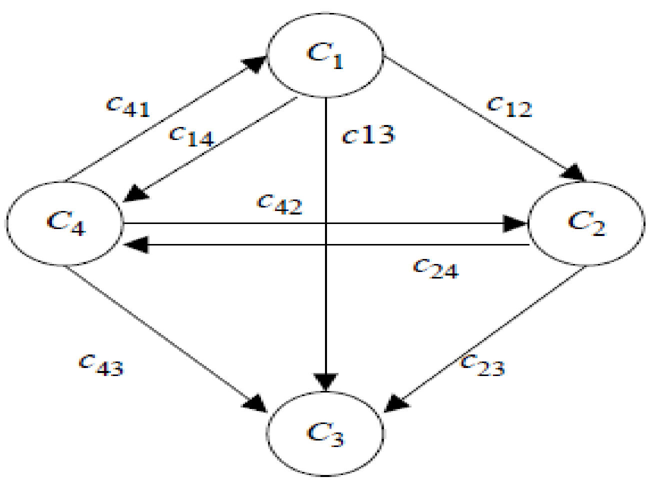

Fig. 6.4:- Customer sensitivity variables diagraph

Hybrid strategies	Appropriate market conditions and operating environment
Pareto 80:20 Using lean method for volume lines, agile methods for slow movers	High level of variety; demand is non proportionate across the range
De-coupling point The aim is to be lean up to the de-coupling point and agile beyond it.	Possibility of modular production or intermediate inventory; delayed final configuration or distribution
Surge/base demand separation Managing the forecast able element of demand using lean principles; using agile principles for the less predictable demand	Where base level demand can be confidently predicted from past experience and where local manufacturing, small batch capacity is possible
Fractal manufacturing partnerships Allows the select suppliers to perform design, manufacture, and assembly operations in close proximity to the OEM	Where the cost of logistics is a major component of total cost and markets are volatile these partnerships would minimize inventory levels for required service levels

Source: Authors based on Christopher and Towill (2001) and Noori and Lee (2000)

Table 6.1. Practical approaches to a leagile supply chain

6.6 Discussion

Managing risks in a supply chain requires lot of information sharing, close relationships and trust on the partners, alignment of incentives and knowledge about risks But an understanding of all these variables is required from a supply chain perspective as failure of any one link would have a cascading effect on all the partners. The model presented in this chapter can be used as an aid to understand and develop suitable supply chain strategy based on required customer sensitivity and risk alleviation competency dimensions. This would facilitate the supply chain managers to infer about the improvements needed if they want to migrate from one model to another model of managing their supply chains in view of changing market requirements.

To illustrate the dynamics of the proposed model, three case studies from Indian SMEs sector were carried out and the values for customer sensitivity index and risk alleviation competency index are presented in Table 6.2. It was found that risk alleviation competency index and customer sensitivity index for garments supply chain is the highest among all the three case supply chains. This can be attributed to garments supply chain's need to be highly responsive as the customer preferences in fashion markets changes very fast and so it should have the capability to quickly respond to the fast changing market requirements. Also this supply chain had improved on the variables that determine the overall supply chain risk alleviation competency. As the values of both the indexes are high garment cluster supply chains should imbibe agile supply chain principles. For the leather goods supply chain both the customer sensitivity index and the risk alleviation index have moderate values so we can apply leagile strategy to leather supply chains. This strategy is appropriate as the demand can be broken into two components – one the demand of saddlery where the variability in demand and variety is low and the other component of leather garments and footwear where the demand and variety required is on the same lines as for fashion goods. The first component of the demand can be met by lean principles while the variable component by applying agile concepts.

The machine tool supply chain is low both on customer sensitivity index and risk alleviation index which implies that currently it is more or less working on the lines of traditional supply chain principles. But as the marketplace requirements of machine tools makes the demand and variety more or less constant for a significant interval of time, the focus should be more on elimination of waste, i.e. it can be structured as lean supply chain.

Supply chain cluster	Customer sensitivity index	Risk alleviation competency index
Garments	550	524
Machine tools	24	109
Leather	340	334

Table 6.2. Comparison of three SMEs cluster supply chains.

Source Authors based on Christopher and Towill (2001) and Noori and Lee (2000)

Chapter 7

Concurrent Design of A Supply Chain Network for X-Abilities Using MADM Approach

7.1) Introduction

Ever growing demand of supply chain networks for high productivity and performance includes use of supply chain network for variety of applications making it a vital business tool. Organizations are constantly finding new applications to make best use of information technology to interact with their customers, employees and business partners. These applications include Enterprise resource planning applications, specialized functional business applications, web-based information access (intranet, internet and e-commerce) and voice over IP, etc. Therefore deployment of single infrastructure for multi-service supply chain network supporting data, audio and video applications becomes essential for normal business operations. Designing such a network is a critical task for management and network designers.

Designing a supply chain network that supports converged applications requires careful considerations of type of applications that the network needs to support and the types of networker resources these applications require. There are a number of issues that must be considered for the network design; some are common to all applications, while others pertain to a subset of applications. Data of some users is more important than that of others. Data and access security is important to key systems. Continuous availability of supply chain network is critical. This requires design of supply chain network having various abilities – performance, resilience, security and maintainability – called x-abilities with more or less equal importance.

Designing supply chain network for performance, resilience, security and maintainability one at a time is not only time consuming but also requires various iterations as design requirements/constraints for ability considered at later stage may require revisiting design for ability already considered.

Many of the research contributions have been published in the field of performance optimization, reliability, security, and maintenance of supply chain network. Most of these studies focus each ability of supply chain network at a time. On the other hand almost all of the studies focus each ability of supply chain network at a time. On the other hand almost all of the studies published in the area of design for x-ability and concurrent design are in the field of manufacturing, construction, etc. Relatively little attention is given on concurrent design of supply chain network for x-abilities, at the same time hardly any literature is available for selection of supply chain network elements using multi attribute decision making (MADM approach).

This article attempts to propose a concurrent design methodology for design of a supply chain network for x-abilities using MADM-approach. This design for x-abilities enable the designers to focus on various abilities at conceptual stage on one hand and concurrent design approach helps reduce design time considerably. TOPSIS technique using MADM approach ensures that the chosen alternative is as close to the ideal solution as possible, and as far from the negative-ideal solution as possible.

7.2) Design Flow/Methodology

A combined approach of concurrent engineering design for x-abilities is proposed. Concurrent engineering design methodology enables faster design cycle by using principles of concurrent engineering that is simultaneous consideration of design constraints, combining experts from different fields into a design team, etc. design for x-abilities is system approach that simultaneously considers all the design goals (abilities).

7.2.1) Design for x-abilities

The design for x-abilities refers to considering simultaneously all product or application specific design goals (abilities) and constraints at the beginning of the design. Various products/services require many of the abilities in varying degree of importance to suit application specific needs. For example to design/build an optimum supply chain network understanding of inherent attributes, properties, strengths and weakness of supply chain network is required. A supply chain network may need to satisfy certain performance requirements for a set of applications to work efficiently in addition to be able to recover from failure, to ensure data security, and ease of maintenance, this requires the supply chain network to have the x-abilities that are performance, resilience, security and maintainability.

7.2.2) Concurrent engineering design

Concurrent engineering design is a systematic approach to integrate the concurrent design of products/services and processes used to design, manufacture, and support the product/service. In this approach, the design team considers all elements of the product life cycle from conception through disposal including quality, cost, schedule and user requirements, for example, concurrent design of supply chain network includes design of a network simultaneously for all the required abilities that are performance, resilience, security and maintainability etc.

7.2.3) MADM technique

MADM techniques are product selection techniques. Multiple attributes are processed in MADM techniques for ranking finite number of alternatives to arrive at a single choice for the best product. This article uses Technique for Order Preference by Similarity to ideal solution (TOPSIS) MADM technique to select a best possible supply chain network element. The specifications of supply chain network elements are considered as attributes for arriving at best possible supply chain network element to deploy in the supply chain network having required ability.

7.3) Concurrent Design of Network for x-abilities

7.3.1) Design flow

Figure 7.1 shows the design flow of a proposed design methodology. The design of supply chain network starts with specifying network objectives and considering application requirements of users. Experts or team of experts from different fields work simultaneously to design supply chain network possessing respective ability that are performance, resilience, security and maintainability. Four parallel paths represent this, each for an x-ability in design flow. Each different team intends to identify pertinent attributes concurrently for each x-ability considering technological and infrastructure standards, specifications, features and constraints. Three over-lapping steps of collecting design information technological and infrastructure considerations show this. The design teams then use these pertinent attributes to select specification of technology and network elements with their relative importance as shown by two overlapping steps of selecting specifications and assigning relative importance. All the specifications selected by different teams individually for each x-ability are united maintaining their relative importance. Ranking and selection of supply chain network elements is then done using TOPSIS method – a MADM approach.

7.3.2) Design goals

Design goal of the supply chain network defines the purpose of design of supply chain network. The predetermined performance criteria or abilities required for applications are considered. For example, if the application demands a guaranteed two second response time for any network transaction, the network design will need to take this into consideration and may place performance optimization as high priority. Following are some of the common abilities that almost all supply chain networks possess with varying degree of importance based on application.

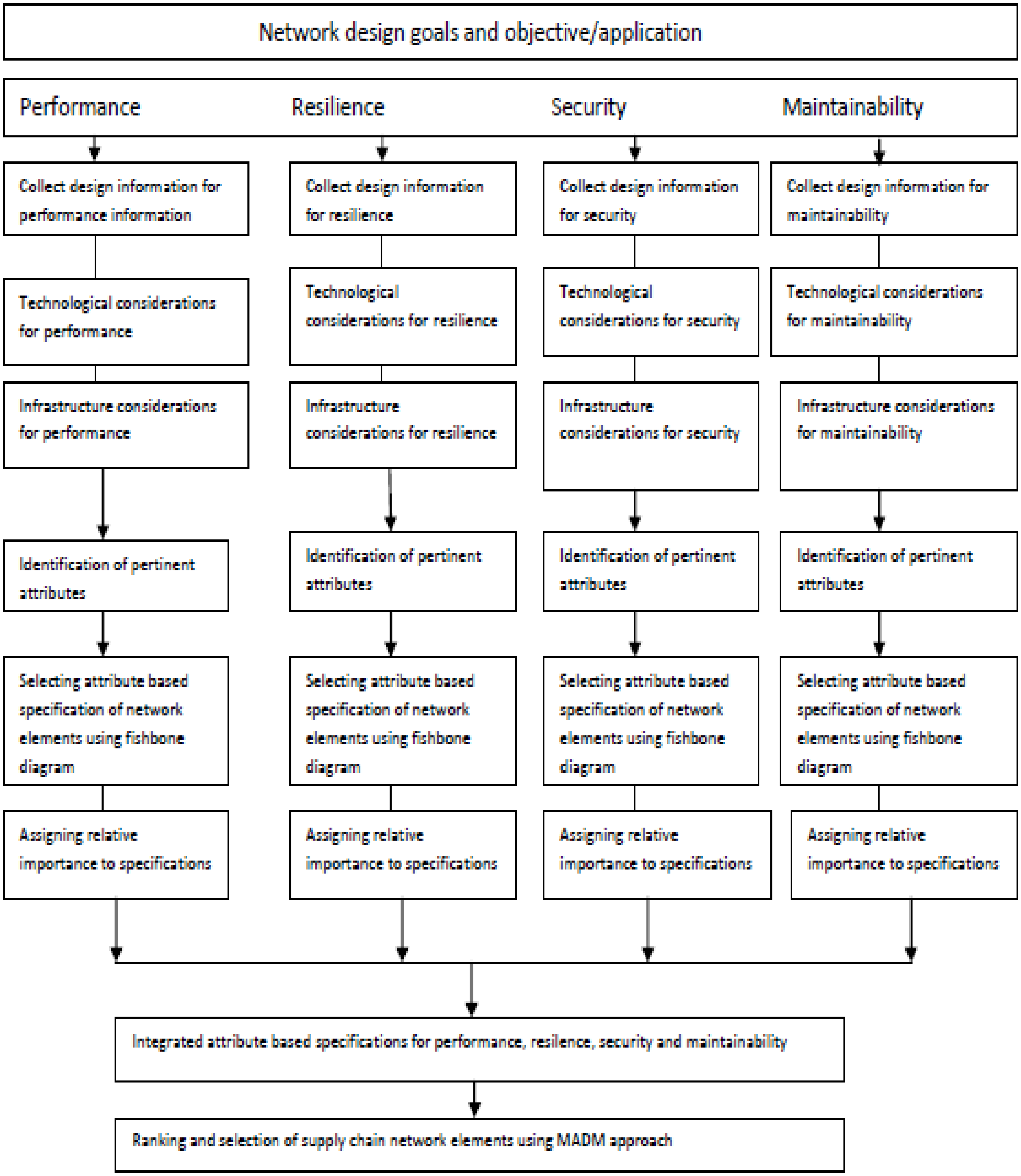

Fig 7.1 Design flow for concurrent design of supply chain network for x-abilities

7.3.2.1) Performance

The performance requirements play an important role in design of supply chain network. The accuracy of data delivered is most important. Slow response time may not effect performance requirement of HTTP or FTP applications. Delays in packet/data delivery will not be acceptable to applications such as video over IP applications. Hence, performance requirements need to be considered at initial stage of deciding network objective and application requirements.

7.3.2.2) Resilience

Resilience refers to the ability of supply chain network to respond to or resist failure and restore to normal working condition. Availability of network for usage is critical for an organization. A resilient supply chain network provides reliable fail-over mechanisms – either within the device or by working in concert with these network elements so that all network devices can be utilized simultaneously. Truly resilient network devices the maximum amount of network uptime without requiring an entire duplicate network. Resilience is one of the key ability to be considered initially while designing a network.

7.3.2.3) Security

More networks are being attacked and threatened, in more devious and creative ways, than ever before. Incidents range from viruses and worms and hacking of data from the network and internal sabotage. Though security is achieved through an ongoing process of assessing risks, managing risks, and monitoring the effectiveness of risk mitigation techniques, a due consideration to security issues is initially required to save a lot of efforts in upgrading and tackling security issues at later stages.

7.3.2.4) Maintainability

Maintainability refers to the ability to retain and/or restore the network in proper working condition. Maintainability includes ability of supply chain network for easy of application deployment, application management, storage/backup, preventive maintenance etc. Maintainability is an important ability to be considered before network is put in place.

7.3.3) Design Technological, and Infrastructure Considerations

After establishing design goals, the next step is to form design teams that will identify relevant attributes for a particular x-ability. Separate teams are formed for each x-ability that will work concurrently to reduce design information required to identify relevant attributes considering application requirements. For example a design team working on performance ability is required to consider attributes like bandwidth and response time for data transfer requirement and execution of application for remote terminal. Similarly a design team working on maintainability is required to consider the relevant attribute like scalability to allow for expansion of future requirements. In the next stage, various technological and infrastructure issues are to be taken into account. For example which technology to use for the LAN/WAN, how should the network design look, what equipment is required, how should it grow, how should it be managed, what will be the future requirements, what is the deployment schedule, etc. are the important issues for consideration by the design team.

7.3.3.1) Identification of Pertinent Attributes for X-abilities

A list of some of the common attributes for a particular ability is shown below. All attributes for a particular ability is shown below. All attributes may not be relevant for all applications. There may be some of the attributes that are relevant and not included in the list.

Performance attributes

Following are some of the key attributes, which can be considered while designing a supply chain network for performance are as followed throughput, response time and delay, accuracy and packet loss, bandwidth, quality of service, network architecture, routing and load balancing accessibility.

Resilience attributes

Important attributes of supply chain design for resilience could be as followed fault avoidance, fault tolerance, failure resistant, nondisruptive maintenance and availability management.

Security attributes

Techniques for designing a secured supply chain network are listed as followed network security, transaction security, data security and server security

Maintainability attributes

Design for maintainability of supply chain network can be achieved by providing the facilities and abilities mentioned as followed scalability, network hierarchy, modularity/open standards/heterogeneity, operations and network management and reachability.

7.3.4) Identification of Specification of Network Elements

7.3.4.1) Selection of Attribute based Specification of Network Elements

In the next step the design teams intend to select and assign relative importance to specifications of network elements which will be put to achieve the designed goals. For this each specification of each network element like main memory, clock speed, internal storage capacity and processor type etc. of server- is considered one at a time for each pertinent attribute identified in section 7.3.3. Each specification, which contributes to add value to attributes and in turn to an x-ability,

is identified. Relative importance is assigned to each specification based on the number of relevant attributes it adds value or influences for all x-abilities taken together.
The selection of specifications of network elements and their relative importance is achieved using fishbone diagrams as shown in figures.

The fishbone diagram, also referred to as root-cause-analysis, provides a systematic way of looking at effects and the causes that create or contribute to those effects. Though fishbone diagram found applications mainly in studying a problem /issue to determine root cause, it can be used to identify specifications that contribute to a feature /ability during design of a product/service. As can be seen from figure 7.2, all the attributes which add value to performance of supply chain network identified in the "Performance Attributes" are represented by major bones of fishbone diagram. For example the higher the throughput the better the performance. Throughput is defined as the amount of data sent that can be sent through a network in a given time. In order to have higher throughput and in turn better performance of supply chain network, higher values of those specifications of network elements are preferred which contribute to achieve better throughput. Sub-bones in the fishbone diagram of figure 7.2 shows that throughput achieved by the supply chain network is directly proportional to data rate, buffer size and capabilities like cut-through switching, full duplex mode etc. In this way, relevant features/specifications for the entire network elements are identified, which contribute to add value to each attribute as represented in a fishbone diagram of figure 7.2.

Similarly fishbone diagram for each x-ability is prepared. They all represent resilience, security and maintainability of supply chain network. All the attributes identified in the section 'Resilience attributes' – that adds value to resilience of supply chain network are represented by major bones of fishbone diagram. Thus for better fault avoidance and in turn, better resilience of supply chain network, network elements with better values of those specifications are preferred, which give rise to achieve better fault avoidance. Fault avoidance is directly proportional to reliability, correctness, robustness/reusability and extendibility of supply chain network. Sub-bones in figure shows this.

Likewise, major bones of figure represents all the attributes which adds value to security of supply chain network are identified in section 'Security attributes'. In order to have better transaction security and in turn better security of supply chain network higher values of those specifications of network elements are preferred, which contribute to achieve better transaction security. Sub-bones in the fishbone diagram of figure exhibit that transaction security can be improved by providing facilities/features like secure socket layer which in turn improves transaction security giving rise to better security of supply chain network.

In the same way maintainability of supply chain network can be improved by having better values of attributes like scalability, network hierarchy, modularity, reachability, better deployment and management of applications. Major bones of fishbone diagram in figure denote this. Sub-bones in figure further denotes basic foundation to achieve better values of these

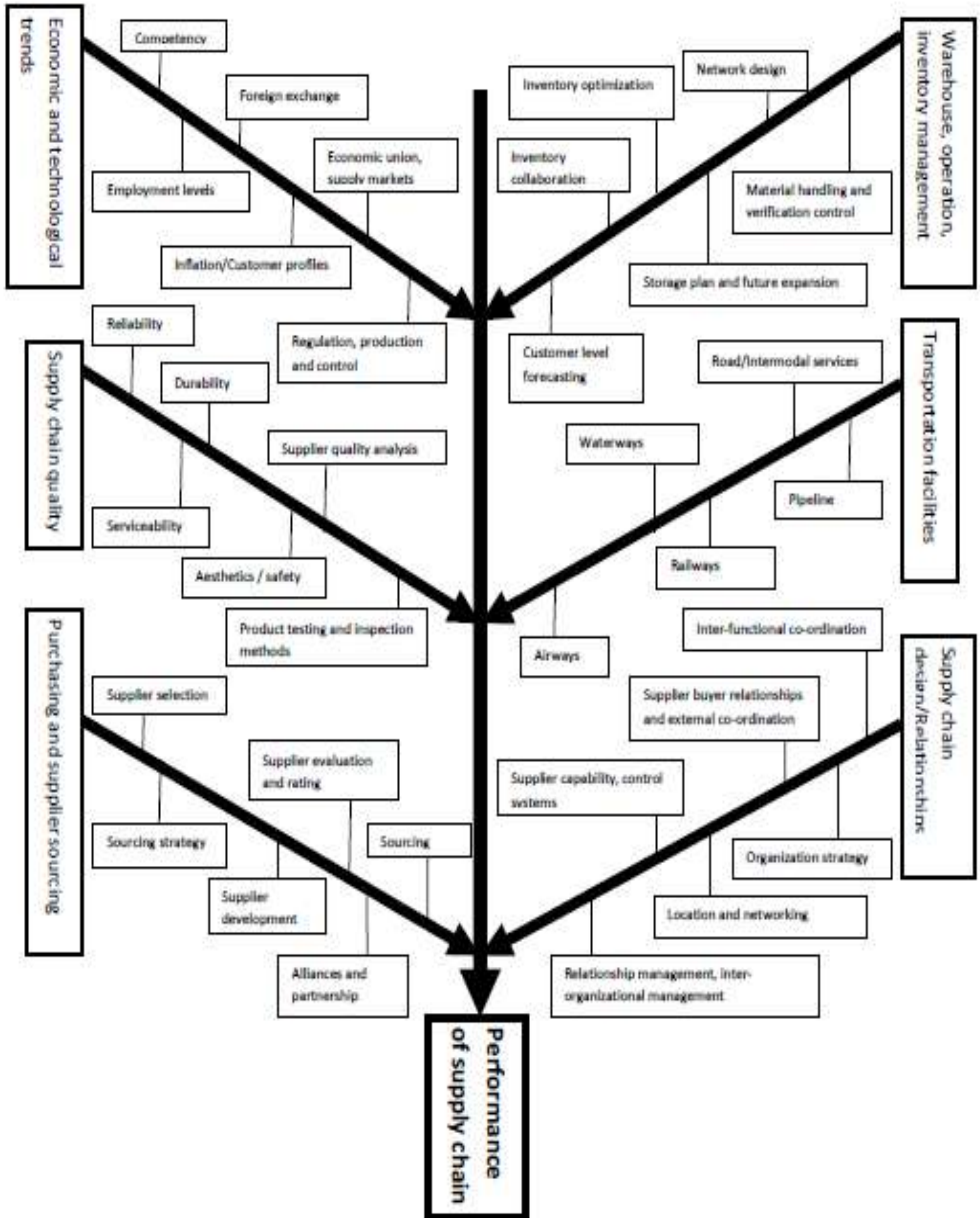

Fig. 7.2 Fishbone diagram (Performance)

attributes. For example scalability can be improved by having higher values of no. of port, data rate and buffer/frame size of router.

7.3.4.2) Assigning relative importance to these specifications

Experts in the field assign relative importance to these specifications using various yardsticks. One such yardstick can be the number of relevant features it adds value or influences a specification in a fishbone diagram. For example, in the fish-bone diagram of figure 7.2 for performance, it can be seen that, the data rate of router influences five relevant attributes. These are throughput, influences five relevant attributes. These are throughput, response time/delay, bandwidth and QoS and routing/load balancing. Multicast support influences four relevant attributes – throughput, bandwidth, QoS and routing/load balancing – and congestion control influences the only relevant attribute of routing/load balancing. Hence, relative importance of these specifications can be approximated to 5, 5, 4, 1, 1 and 1 respectively, for data, buffer size (maximum memory), multicast support; label based routing, congestion control and flow control of router.

Similarly, fishbone diagram of figure gives relative importance of specifications of router for resilience. The specification buffer sizes (maximum memory) influences the one attribute – fault avoidance – and number of ports influences three of the attributes – fault avoidance, fault tolerance, failure resistant. Hence relative importance of specifications can be 1, 3, 1, 3, 3, 1 and 1 for buffer size (maximum memory), congestion control and processing capacity, number of ports, routing/forwarding, auto configuration and standard protocols/interfaces, respectively. Figure gives relative importance of buffer size (maximum memory) and processing capacity of router for security, which is 5 and 5, respectively. Similarly figure gives relative importance of data rate, buffer size (maximum memory), number of ports and standard protocols/ interfaces for maintainability which is 1, 1, 1 and 1 respectively.

Assigning relative importance is to be repeated for other network elements that are server, desktop PCs, network interface card, cabling system and networking software for each x-ability.

This entire process of sections 7.3.3 and 7.3.4 that is identification, selection of attribute-based specifications of network elements and assigning relative importance to these specifications is to be done concurrently by separate team for each x-ability s as to reduce design time.

7.3.5) Combining results of section 3.4

7.3.5.1) Combination of attribute-based specification for x-abilities assigning relative importance to combined specification.

Now, the results of above four concurrent design steps for each x-ability are to be united to achieve overall goal of design for x-ability. By considering each x-ability to be equally important average relative importance of each specification can be taken as combined relative importance for specification of x-abilities. The average can be taken after calculating relative importance on a common scale. The weightage is subject to the factors under consideration.

Thus to design x-abilities, combined relative importance of specification of router is as follows –

Data rate	1.00
Buffer size (max. memory)	1.67
Multicast support	0.40
Label based routing	0.10
Congestion control	0.60
Flow control	0.10
Processing capacity	0.67
Number of ports	1.00
Routing/forwarding	0.50
Auto configuration	0.17
Standard protocols/interfaces	0.67
Cost	2.46

Table 7.1– Combined relative importance of specification of router

7.3.5.2) Short-listing of alternatives –

Short-listed alternatives may be obtained from different design teams/experts or as suggested by vendors. For example, following routers may be considered suitable for an application under consideration.

Where –
1) Is alternative router model,
2) Is data rate (Mbps)
3) Is maximum memory (MB)
4) Is number of ports
5) Is processing capacity (embedded crypto processor: 1 for yes and 0.7 for no).
6) Is approximate market price of router (in rupees)

The specification label-based routing, congestion control, flow control, routing/forwarding, auto configuration and standard protocols/interfaces are supported by all the short-listed routers and hence these may be omitted during ranking and selection of router.

7.3.6) Ranking and selection using MADM

Now, the selection of supply chain network elements can be done using MADM approach (TOPSIS technique). Figure 7.3 shows a flowchart of the technique. MADA methods choose or rank finite number of alternatives that are measured by few relevant attributes. TOPSIS is the technique used to rank these alternatives. The steps involved are shown with example of selection of router as flows.

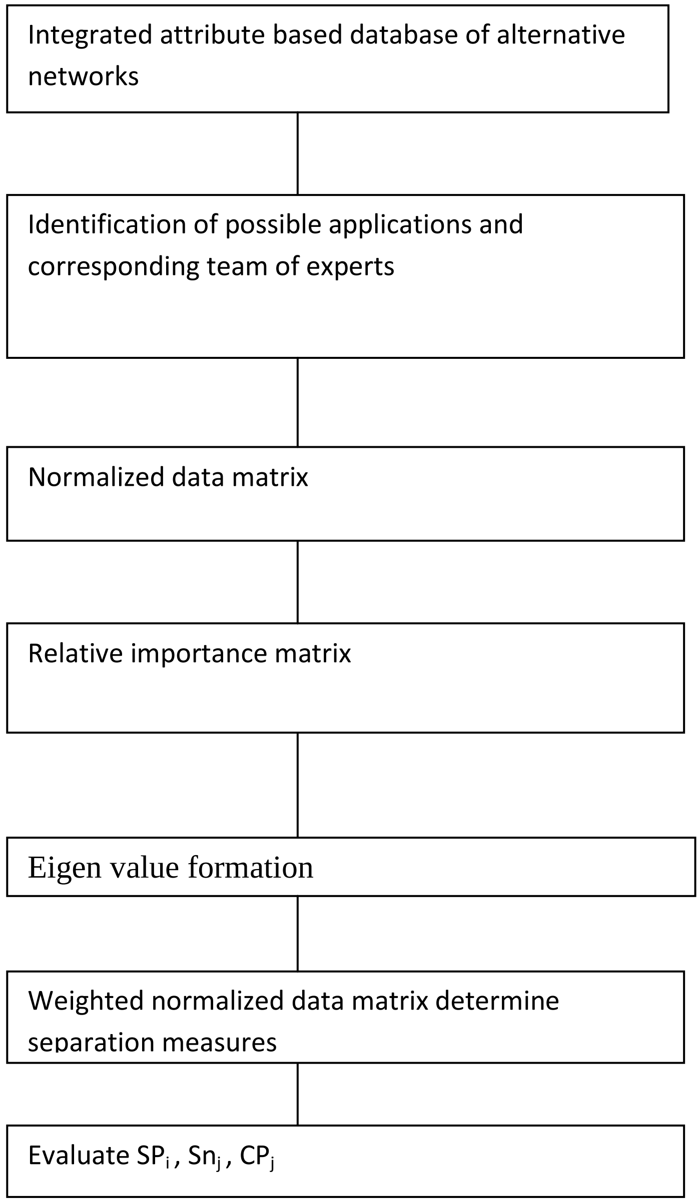

Fig.7.3. TOPSIS flow chart

7.3.6.1) Representation of alternatives as decision matrix

Decision matrix, D, is a (m × n) matrix where each row represents "m" number of short-listed alternatives – router alternatives in our example – and columns represents "n" number of specifications that are data rate, maximum memory, number of ports, processing capacity and cost of router. For cost of the router lowest value is preferred hence inverse of market price is to be considered for computation.

7.3.6.2) Arriving at normalized specification matrix.

Normalized specification matrix, N, provides dimensionless quantities and is calculated using normalization of decision matrix, D, by using –

$n_{ij} = d_{ij}/(\sum_{i=1}^{m} dij)$^1/2

Where d_{ij} is an element of the decision matrix, D. Thus,

$$N = \begin{bmatrix} 0.0499 & 0.1731 & 0.0969 & 0.4082 & 0.6965 \\ 0.0499 & 0.3427 & 0.1938 & 0.4082 & 0.5473 \\ 0.4988 & 0.4617 & 0.2423 & 0.4082 & 0.3483 \\ 0.4988 & 0.4617 & 0.3876 & 0.4082 & 0.2488 \\ 0.4988 & 0.4617 & 0.5330 & 0.4082 & 0.1493 \\ 0.4988 & 0.4617 & 0.6783 & 0.4082 & 0.0095 \end{bmatrix}$$

7.3.6.3) Computation of relative importance matrix –

Relative importance matrix, A, is formed by storing pair-wise comparisons of relative importance of specification obtained in section 7.3.5.2. this is an (m × n) matrix where a_{ij} contains the relative.

$$A = \begin{bmatrix} 1.00 & 1.67 & 1.00 & 0.67 & 2.46 \\ 1.67 & 1.00 & 1.67 & 2.49 & 0.68 \\ 1.00 & 0.60 & 1.00 & 1.49 & 0.41 \\ 0.67 & 0.40 & 0.67 & 1.00 & 0.27 \\ 2.46 & 1.47 & 2.46 & 3.67 & 1.00 \end{bmatrix}$$

7.3.6.4) Calculation of relative weights of the specifications –

In the next step relative weights of the specifications can be calculated by Eigen vector method using following steps -

1) Take Eigen values of relative importance matrix A, χ_{max} corresponding to the largest Eigen value λ_{max} , as all the elements of χ_{max} are either positive or negative.

2) Find the sum of the elements of $\chi_{max;}$

3) Find the weight vector *w* using *w* = $(\chi_{max})/\alpha$

Performing these three steps gives relative weights:

W_1 = 0.2603, W_2 = 0.2130, W_3= 0.1277, W_4 = 0.0853, W_5 = 0.3136

7.3.6.5) Weight assignment

Assigning weights to normalized specification matrix gives weighted normalized specification matrix "V"

$$V = \begin{bmatrix} w1n1{,}1 & w1\,n2,2 & wn\,n1,n \\ w1\,n2,1 & w2\,nm,2 & wn\,n2,n \\ w1\,nm,1 & w2\,nm,2 & wn\,nm,n \end{bmatrix}$$

Therefore putting values, we get the results as discussed ahead.

7.3.6.6) Ranking and selection by TOPSIS

Ranking ad selection of network elements, router, is done using TOPSIS method.

The separation from the positive benchmark network element, SP_i, is

$SP_i = [[\sum_{i=1}^{n}(Vij - V*)^2]\ ^\wedge 1/2$ (i = 1.2….m)

From the negative benchmark network element SN_i, is –

$SN_i = [\sum_{i=1}^{n}(Vij - V-)^2]\ ^\wedge 1/2$ (i =1,2…...m)

Then the relative closeness to the positive benchmark network element, CP, is calculated using –

$CP = SN_i / (SP_i + SN_i)$

The calculated values are,

CP_1 = 0.1959, CP_2 = 0.1961, CP_3 = 0.5786, CP_4 = 0.5343, CP_5 =0.4901, CP_6 =0.4855

Ranking of the network element is done in descending values of CP i.e., most preferred network element has maximum CP value. A network element with largest CP is preferable i.e., CP_3 router is preferable for x-abilities under consideration.

Supply chain program MATLAB: A MATLAB program is developed for performing calculations of above procedure from steps 7.3.6.1 to 7.3.6.6. The MATLAB program developed requires decision matrix “D” and relative importance matrix “A” a as input and after performing the remaining calculation gives ranking in the form of CP values as output.

The selection procedure described in Sections 7.3.4-7.3.6 is iterated for each network element subset to arrive at optimum supply chain network for the x-abilities under consideration.

Chapter 8

Supplier selection and order allocation based on fuzzy SWOT analysis and fuzzy linear programming

8.1. Introduction

Companies try to reduce costs and manage risks. It is important to know that one of the major portions of the firms' expenses is related to logistics activities which mostly are more than 50% of all companies' costs (Aissaoui, Haouari, & Hassini, 2007). Therefore, companies try to manage purchasing tasks. Experts believe that supplier selection is one of the most prominent activities of purchasing departments (Xia & Wu, 2007). But, supplier selection is a difficult problem for managers because the performances of suppliers are varied based on each criterion (Liu & Hai, 2005). In the previous investigations, several methods have been suggested to solve the supplier selection problem. However, the most of them have not paid attention to the strategic perspective. SWOT (Strengths, Weaknesses, Opportunities and Threats) is a useful technique which is commonly known in strategic management area. SWOT analyzes the external opportunities and threats as well as the internal strengths and weaknesses. Besides, it is one of the most famous tools for strategy formulation. The goal of the analysis of external opportunities and threats is to evaluate whether a company can capture opportunities and avoid threats when facing an uncontrollable external environment such as change in the rule of law (Chang & Huang, 2006). SWOT can also be used when strategy alternative emerges and the relevant decision context needs to be analyzed (Christensen, Berg, & Salter, 1976). On the other hand, the majority of papers assume that the demand is deterministic, but in reality this assumption is not true (Snyder, 2006).

In this chapter, we use quantified SWOT analysis as a decision tool to formulate strategic plans for supplier selection. To our knowledge, no one has applied SWOT analysis in supplier selection. Furthermore, fuzzy logic has been integrated with SWOT analysis to deal with vagueness and imprecision of human thought. The proposed decision model is more comprehensive and competitive rather than other published MCDM models for supplier selection due to its dynamic nature and strategic oriented. This model has been implemented in a company that manufactures automobile. The company intends to buy products from multiple supplies. Furthermore, we utilize a proposed fuzzy linear programming model to determine the order quantity from each supplier. In this model, demand is a fuzzy number. The output of SWOT analysis is applied as an input in the mathematical model. The majority of previous models suppose that there is a single product, but our model has been designed for multiple products. In addition, the capacity of warehouse is taken into account as a constraint. The organization of this chapter is as follows: Section 8.2 discusses the literature review. Fuzzy logic is presented in Section 8.3. In Section 8.4, a case study is illustrated.

In the first phase, suppliers are assessed based on fuzzy SWOT analysis. Then, the order quantity is determined by a fuzzy linear programming model. Subsequently, discussion is presented in Section 8.5. Finally, conclusions are presented in Section 8.6.

8.2. Literature review

Supplier selection is a multi criteria decision-making problem Criteria and decision-making techniques are two important elements in a supplier selection problem. Dickson (1966) was one of the first ones in this field of study. He identified 23 different criteria for supplier selection based on a questionnaire sent to managers of companies of North America. These criteria include quality, delivery, performance, warrant and claim policy, production facilities and capacity, net price, and technical capabilities. Moore and Fearon (1973) presented a review where focused on industry applications of computer-assisted supplier selection models. Weber, Current, and Benton (1991) categorized the literature on supplier selection by reviewing 74 articles. They identified price, delivery, quality, facilities and capacity, geographic location, and technology capability. De Boer, Labro, and Morlacchi (2001) identified four stages in supplier selection problem which consist of problem formulation, formulation of criteria, qualification and final selection. They stated that the majority of authors have focused on final selection stage. Degraeve, Labro, and Roodhoofi (2004) presented some published supplier selection models and compared their relative efficiency using the total cost of ownership. Aissaoui et al. (2007) have presented another literature review according to the purchasing process. Their proposed classification is based on single and multiple items and periods.

8.2.1. Supplier selection based on fuzzy logic

Uncertainty is one of the most challenging but important problems in SCM (Melo, Nickel, & Saldanha-da-Gama, 2009; Snyder, 2006). In order to solve the problem of ambiguity of the attributes' outcomes in the realistic environment some researchers have used assorted methods based on fuzzy sets theory (FST) and fuzzy logic. Li, Fun, and Hung (1997) used fuzzy sets theory in supplier selection problem to consider imprecise data. Kwong, Ip, and Chan (2002) presented fuzzy expert system for supplier assessment; however, application of their proposed method is difficult in practice. Kahraman, Cebeci, and Ulukan (2003) utilized fuzzy analytical hierarchy process to select the best suppliers. Jain, Tiwari, and Chan (2004) evaluated the supplier performance using an evolutionary fuzzy-based approach and linguistic variables. Kumar, Vrat, and Shankar (2004, 2006) focused on fuzzy goal programming to solve a vendor selection problem. They minimized cost, rejections and late deliveries simultaneously. Bevilacqua, Ciarapica, and Giacchetta (2006) suggested a method that utilizes the house of quality concept for the supplier selection, but they ignored quantitative metrics. They used triangular fuzzy numbers. Bottani and Rizzi (2006) presented a fuzzy approach for the selection of the most suitable 3PL service provider. They applied fuzzy TOPSIS. Chou and Chang (2008) presented a fuzzy multi attribute rating technique approach for solving the vendor selection problem from the perspective of strategic management. They utilized triangular fuzzy numbers; however, the model does not regard external criteria such as opportunities and threats. Amin and Razmi (2009) proposed an integrated model which covers supplier selection, evaluation and development stages. Besides, they applied a fuzzy- based algorithm for selecting the best Internet service provider (ISP). In other words, they examined the supplier selection in service environments. The most of above literature has discussed the strengths and weaknesses of the suppliers without considering the external attributes and strategic perspective. In the proposed method it will be illustrated that how the SWOT method can be applied to respond this shortage.

8.2.2. Supplier selection and order lot sizing

Some authors not only solve the supplier selection problem, but also they determine how much should be purchased from each selected supplier. The majority of these papers have written in manufacturing environments. Ghodsypour and O'Brien (1998) combined analytical hierarchy process (AHP) and linear programming to consider both tangible and intangible factors in supplier selection problem. However, their model is deterministic and does not consider uncertainty in human though. In this chapter, we extend their model. Weber, Current, and Desai (2000) utilized DEA for evaluating the suppliers and multi-objective programming for determining the vendor order quantity. Kim, Leung, Taepark, Zhang, and Lee (2002) considered a supply network consisting of a manufacturer and its suppliers. They formulated a nonlinear programming model and determined how much of each raw material and component part to order from which supplier according to the capacity of suppliers and manufacturer. It is assumed that demand is stochastic. However, they only determined the order quantity and they did not select the suppliers. Liao and Rittscher (2007) proposed a multi-objective supplier selection model under stochastic demand conditions. Stochastic supplier selection has been determined with simultaneous consideration of the cost, quality, delivery and flexibility according to the limitations of capacity. Xia and Wu (2007) presented a new method based on analytical hierarchy process improved by rough sets theory and multi-objective to determine the number of suppliers and the order quantity allocated to these suppliers. In addition, they considered discount. Wadhwa and Ravindran (2007) optimized Price, lead-time and rejects (quality) to select the best vendor in the field of outsourcing. They applied quantity discount in the model. Faez, Ghodsypour, and O'Brien (2009) proposed vendor selection and order allocation using an integrated fuzzy case-based reasoning and mix integer programming model. However, they did not examine strategic issues in the process of supplier selection. Demirtas and Ustun (2008) presented integrated approach of analytic network process (ANP) and multi-objective linear programming for selecting the best suppliers. The main purpose of integrated models is to consider both qualitative and quantitative criteria. According to these papers, most of authors have used multi-objective programming for lot sizing.

8.2.3. SWOT

SWOT is a management tool to formulate strategic action plans. Christensen et al. (1976) developed the SWOT analysis on the basis of Grand Strategy Matrix (GSM). SWOT is an acronym for strengths, weaknesses, opportunities and threats. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favorable and unfavorable for achieving that objective. SWOT maximizes strengths and opportunities, and minimizes threats and weaknesses. In other words, it transforms weaknesses into strengths, and threats into opportunities (Arslan & Deha Er, 2008; Christensen et al., 1976). Kurttila, Pesonen, Kangas, and Kajanus (2000) presented a new hybrid method for improving the usability of SWOT analysis. They combined SWOT and analytic hierarchy process (AHP) to provide information for strategic planning processes. Chang and Huang (2006) also suggested the quantified SWOT analytical method which was adapted to the concept of Multiple-Attribute Decision Making. They used AHP and a multi-layer scheme to simplify complicated problems. They performed SWOT analysis on several enterprises concurrently. It is well known that through AHP, the decision maker is only asked to give judgments about either the relative importance of one criterion against another or its preference of one candidate on one criterion against another. However, when the number of candidates and criteria grows, the pair wise comparison process becomes cumbersome, and the risk of generating inconsistencies grows. In addition, AHP, like many systems which work based on pair wise comparisons, can produce ‘‘rank reversal” results (Dyer, 1990). Yuksel and Dag deviren (2007) proposed analytical network process (ANP) in a SWOT analysis. However, the problems of pair wise comparisons are remained. In this chapter , the SWOT method has been used to analyze the current situation of the suppliers in the competitive market according to strategic viewpoint.

8.3. Fuzzy logic

A fuzzy set is a class of objects with grades of membership. A membership function is between zero and one (Zadeh, 1965). Fuzzy logic is derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. It allows the model to easily incorporate various subject experts' advice in developing critical parameter estimates (Zimmermann, 2001). In other words, fuzzy logic enables us to handle uncertainty. There are some kinds of fuzzy numbers. Among the various shapes of fuzzy number, triangular fuzzy number (TFN) is the most popular one. It is represented with three points as follows: $A = (a_1, a_2, a_3)$. The membership function is illustrated in Fig. 8.1. Let A and B are defined as $A = (a_1, a_2, a_3)$, $B = (b_1, b_2, b_3)$. Then $C = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$ is the addition of these two numbers. Besides, $D = (a_1 – b_1, a_2 – b_2, a_3 – b_3)$ is the subtraction of them. Moreover, E = (a1* b1, a2 * b2, a3 * b3) is the multiplication of them (Klir & Yuan, 1995; Lai & Hwang, 1995; Zimmermann, 2001).

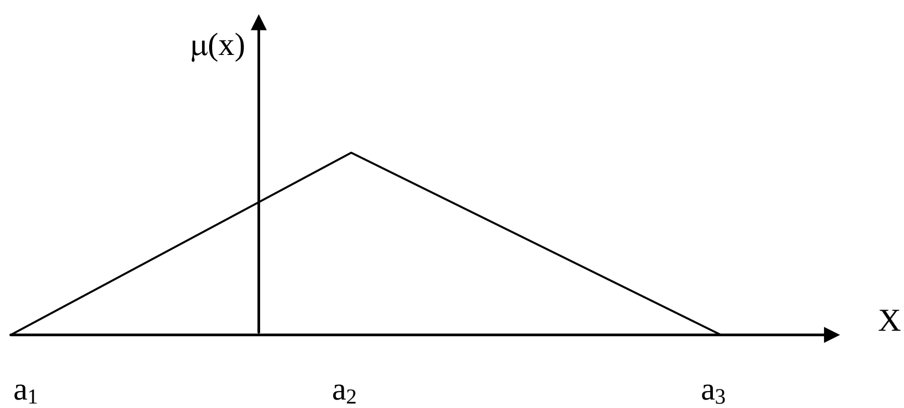

Fig 8.1:- A triangular fuzzy number

8.4. Case study (The values and case study for fuzzy-input has been taken from "Bottani.E and Rizzi.A (2006)

S.G. Company has been established in 1985 as a designing, engineering and supplying company of auto parts but it practically commenced its activities in 1989. This company is a pioneer in supply chain management of auto parts in Iran. S.G. Company supplies the necessary parts of 400,000 automobiles per year for assembly plants, and is planning to increase the production to 500,000 vehicles per year. Its 23 years of efforts and endeavor have led to in the formation of a network of the capable automobile parts suppliers. The services offered by S.G. Company and its main responsibility and strategies are as follows:

– To provide supply planning or localization planning (produce parts in the country). – To identify potential auto-parts manufacturers and to evaluate them.

– To sign supply contracts with auto-part manufacturers or vendors.

– To control the quality of parts.

– To train auto-part manufacturers in order to promote their technical and managerial knowledge.

– To promote and facilitate auto-part export (including joint investment projects, marketing, and commercial services).

Recently, the company is investigated to produce a new automobile. Therefore, the ability and capacity of suppliers should be evaluated. Up to know the majority of manufactured automobiles were sold in Iran. However, in recent years, the quality of products has increased and the final costs have decreased. Thus, the manufacturers plan to export automobiles. The traditional assessment system implies on the internal factors such as cost and quality. But, other factors like mutual trust should be added to shift from national to international market. The S.G. Company divides the parts suppliers into several groups based on the products and collects the necessary information in a data base. Tire suppliers are one of the groups. Wheels and tires are famous components of each vehicle. Nowadays, more than one billion tires are produced every year in the world with the three leading tire manufacturers absorbing more than 60% of a global market share. China, India, Japan, Hong Kong and Thailand are the most well-known manufacturers of tires in the global market. Tiers of automobiles are usually rubber tubes or more specifically pneumatic enclosures affixed around a wheel which facilitate rotation of a vehicle. Almost all types of automobiles ranging from two wheelers, cars, to airplanes use tires. Tires are filled with air, which provides a flexible support to the vehicle. Tires enhance the performance of an automobile by providing a comfortable grip of the road. Tires often are manufactured using ductile elastomeric material like fabric, rubber and wire. The company wants to purchase two types of passenger car tires. In other words, there are two products in this case study. The top management forms a project team. The main purposes of the team are identifying eligible candidates and defining the appropriate criteria, and selecting the best supplier, and ultimately determining the order quantity. The team works under supervision of the head of logistics. Moreover, three experts from purchasing department, logistics department, and information Technology department contribute in decision-making process. Furthermore, two academics from universities participate in the sessions as consultants. The team is obligated to select the suppliers who produce the parts in the country. The proposed method is composed of two sections. In the first phase fuzzy SWOT analysis is applied to evaluate the suppliers. The output of this stage is the weight of each supplier. In the second phase, a fuzzy linear programming model is proposed to determine how much should be purchased from each supplier.

8.4.1. Phase 1: supplier evaluation

This section describes the proposed model to evaluate suppliers. The case study will be progressed simultaneously.

Step 1: List qualified suppliers: In the first step, it is necessary to select a set of suppliers. The members of committee arranged some meetings and decided to publish an advertisement in newspapers to identify the tier suppliers who are interested to contribute in the project. The team announced minimum requirements such as financial ability to filter small and local suppliers. After pre assessment of all existent suppliers (10), five suppliers have been chosen as the best candidates.

Step 2: Research and draft the key factors of internal and external criteria for supplier selection: the key factors consist of both benefit and cost metrics. The academics collected a list of metrics that have been utilized frequently in international scientific journals. The team reviews the list in several meetings to select suitable criteria for supplier selection process. These criteria comprise both qualitative and quantitative ones. Finally, they determined the appropriate criteria by brain storming. Fig. 8.2 shows the selected criteria. In the previous methods, external criteria were ignored, but SWOT enables us to take into account opportunities and threats.

Step 3: Determine the weights of qualified criteria for each supplier using linguistic variables: In this step ask the experts to determine the weights by linguistic variables for all criteria. In this study the proposed scale of Amin and Razmi (2009) is applied to consider the uncertainty in human thought.

Let U = {VL, L, ML, M, MH, H, VH} be the linguistic set used to express opinions on the group of attributes (VL = Very Low, L = Low, ML = Medium Low, M = Medium, MH = Medium High, H = High, VH = Very High). The linguistic variables of U can be quantified using triangular fuzzy numbers as: VL = (0, 0, 1); L = (0, 1, 3); ML = (1, 3, 5); M = (3, 5, 7); MH = (5, 7, 9); H = (7, 9,10); VH = (9,10,10) (please refer to Fig. 8.3). Three decision makers established the level of importance or weight of each of criteria by means of the linguistic variables.

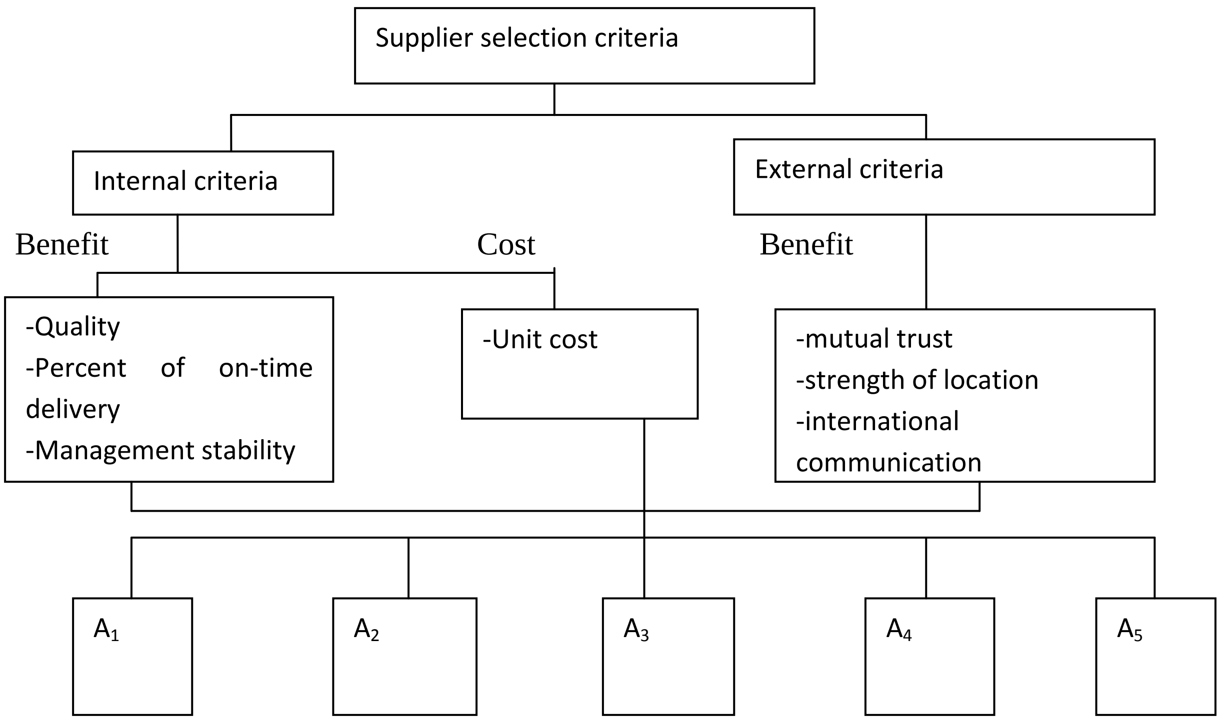

Fig 8.2:- Supplier selection hierarchies

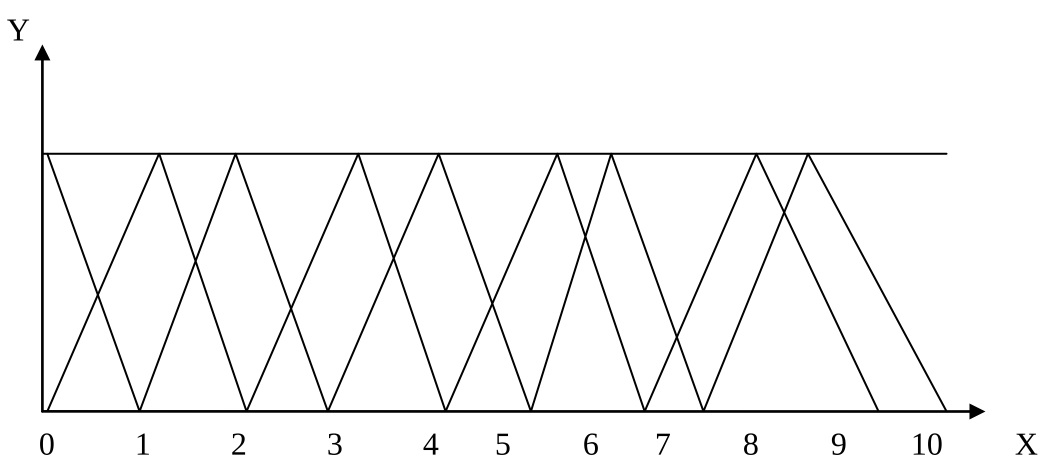

Fig 8.3:- A linguistic scale (Amin and Razmi 2000)

In the proposed model, the triangular fuzzy numbers are aggregated by the following equation:

$$W_{iej} = W_{iej1} \oplus W_{iej2} \oplus \ldots \oplus W_{iejk} / K \quad (1)$$

where k is the number of decision makers and m is the number of suppliers (j = 1,2,. . .,m). Moreover, there are s criteria (e = 1, 2 . . . s). Besides, there are n products (i = 1, 2 . . . n). Some of the selected criteria do not depend on product. For example Management stability is determined based on the condition of each supplier and it is the same for all products of a supplier. The simple and popular method, centroid method is adopted to defuzzify triangular fuzzy numbers use for practitioners. A defuzzified triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is calculated by Eq. (2). Accordingly, other weights will be determined.

$$\text{Defuzzified number} = 1/3 \times (a_1+a_2+a_3) \quad (2)$$

Step 4: Collect the required data for the quantified attributes such as unit cost and delay which have been highlighted by ‘‘QN”. This information is obtained by special forms which have been sent to the candidates.

Step 5: Calculate the weights of criteria by linguistic variables: The importance of each criterion is different. Therefore, the decision makers should determine the priorities between criteria. The supervisor of project was implied to devote enough time to this step. As a result, the three experts dedicated several hours to determine the weights.

Step 6: Normalize the scores by Eqs. (3) and (4): the purpose of normalization is to unify the scales of the key factors. After that, total weighted value can be obtained by multiplying the weights of criteria with normalized scores for each product. Then, determine the benchmarking value for the overall external and internal factors. In this study, the benchmarking value is defined as the average of total weighted values.

Benefit criteria normalization:

$$f_{iej} = W_{iej} / \max_j Wiej \text{ , } i = 1,2,3,\ldots s, \; j = 1,2,\ldots .m. \quad (3)$$

Cost –criteria normalization:

$$f_{iej} = \min_j W_{iej} / W_{iej}, \; i = 1,2,3,\ldots n, \; e = 1,2,\ldots .s, \; j = 1,2,\ldots .m \quad (4)$$

Step 7: Calculate the coordinated values for each supplier by Eqs. (5) and (6), and compare the results. Then, demonstrate these values on the four-quadrant coordinate: firstly, the benchmarking value is subtracted from total weighted scores. The final value will be the coordinated value of the compared supplier in the SWOT matrix. The coordinated value will be within 1 and +1. The supplier possesses strengths and opportunities when the coordinated value is larger than the benchmarking value. On the other hand, the supplier is comparatively weak and faces threats when the coordinated value is smaller than the benchmarking value.

$IC_{ij} = I_{ij} - IB_i \quad i = 1, 2 \ldots n, j = 1; 2; \ldots m$ (5)

$EC_{ij} = E_{ij} - EB_i \quad i = 1; 2; \ldots; n; j = 1; 2; \ldots m$ (6)

where IC_{ij} is the internal coordinated value of the jth supplier for product i, Iij is the internal total weighted value of the jth supplier for product i, IB_i is the benchmarking value of the internal assessment for product i, EC_{ij} is the external coordinated value of the jth supplier for product i, E_{ij} is the external total weighted value of the jth supplier for product i, and EB_i is the benchmarking value of the external assessment for product i. By calculating the benchmarking and coordinated values according to the above formulas, two groups of data can be obtained: one is the coordinated value used to compare the internal assessment of the suppliers; the other is the coordinated value used to compare the external assessment of the suppliers.

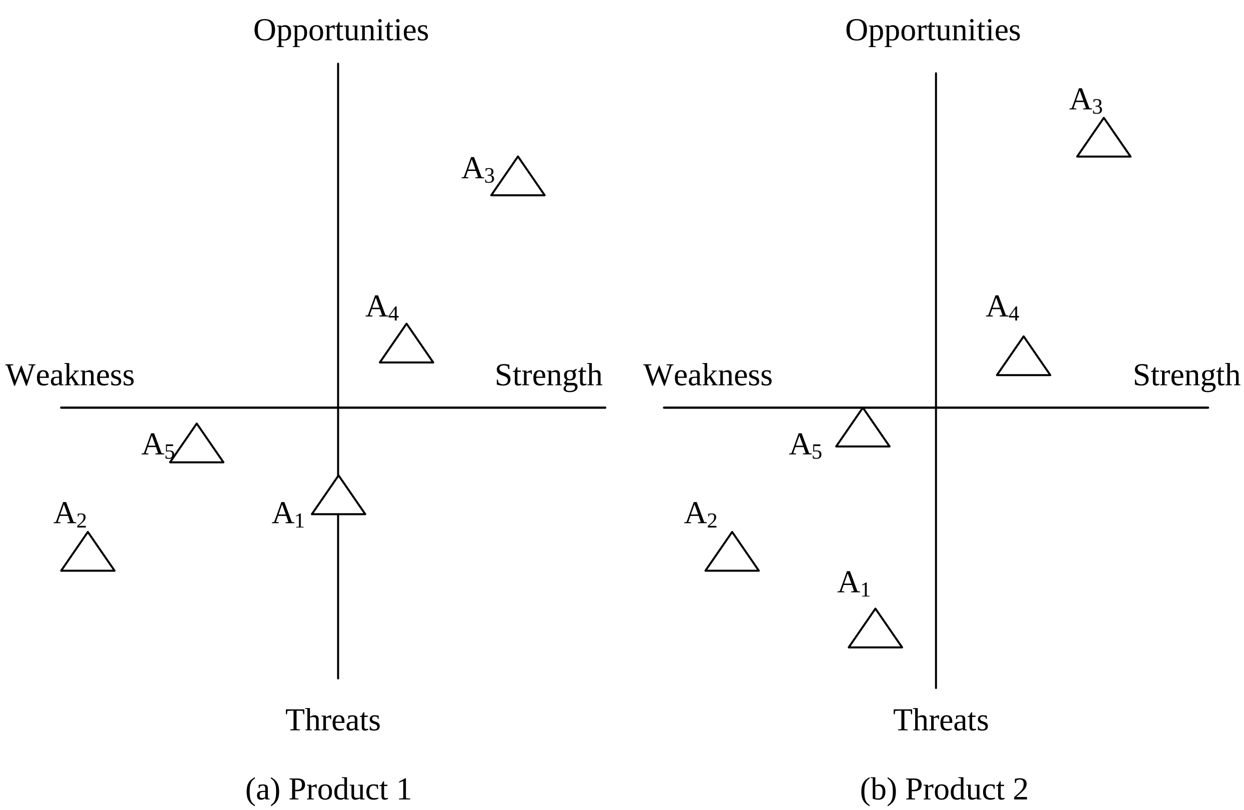

Fig 8.4:- SWOT Analysis

Now each supplier has coordinates of x and y, therefore its position in the competition can be clearly depicted. It is important that each x and y is defined for each product. After drawing the SWOT matrix, the most suitable suppliers can be selected by comparing suppliers' position in the matrix. It is well known that the position in the quarter of strengths and opportunities is the most suitable position in this figure. The members of team followed the steps 6 and 7 and performed the algorithm. Besides, Fig. 4 shows the position of suppliers in the competition. The figure can help the manager of company to evaluate suppliers very quickly. As it can be seen from Fig. 8.4 suppliers A3 and A4 are located in the first quadrant. It means that these two suppliers have external opportunities for development and potentially have internal competing strength to get the opportunities. Therefore, it can be concluded that they are in the best position for facing competition. Suppliers A1, A2, and A5 (in the third quadrant) has low competitive strength and facing threats from other competitors.

8.4.2. Phase 2: order quantity

In the next phase of supplier selection, the order quantity should be determined. In this section, we propose a mathematical model (linear programming) to determine how much should be purchased from each supplier. In the majority of papers in the field of supplier selection, the order quantity is determined for a single item. However, we assume that each supplier produces multiple products. In addition, it is supposed that the demand is a fuzzy number.

8.4.2.1. Notations

Decision variable

χ_{ij} = the amount of product i (i = 1, 2, . . .n), purchased from supplier j (j = 1, 2,. . .,m)

Model parameters

α_1 = weight of internal criteria

α_2 = weight of external criteria

I_{ij} = internal total weighted value for product i and supplier j from SWOT analysis

E_{ij} = external total weighted value for product i and supplier j from SWOT analysis

D_i = fuzzy demand for the product i

v_{ij} = capacity of supplier j for product i

t_{ij} = minimum purchase quantity of product i from supplier j according to the purchasing strategy

d_i = unit volume of product i

$b_i =$ total capacity of warehouse for product i

8.4.2.2 Mathematical model

Max $\sum_{i=1}^{n} (\alpha 1 Iij + \alpha 2 Eij) Xij \, \Sigma^{m}_{j=1}$ (7)

s.t. $\sum_{j=1}^{m} Xij = D_i \quad \forall i$ (8)

$\chi_{ij} \leq v_{ij} \quad \forall i, j$ (9)

$t_{ij} \leq X_{ij} \quad \forall i, j$ (10)

$\alpha_1 + \alpha_2 = 1$ (11)

$\sum_{i=1}^{n} d1 \chi ij \, \Sigma^{m}_{j=1} \leq \sum_{i=1}^{n} bi$ (12)

$\chi_{ij} \geq 0$, i= 1,2…..m (13)

θ	D_1	D_2	χ_{11}	χ_{12}	χ_{13}	χ_{14}	χ_{15}	χ_{21}	χ_{22}	χ_{23}	χ_{24}	χ_{25}
0	1000	860	100	0	500	400	0	100	0	500	260	0
0.1	1020	877.2	100	0	500	420	0	100	0	500	277.2	0
0.2	1040	894.4	100	0	500	440	0	100	0	500	294.4	0
0.3	1060	911.6	100	0	500	460	0	100	0	500	311.6	0
0.4	1080	928.8	100	0	500	480	0	100	0	500	328.8	0
0.5	1100	946	100	0	500	500	0	100	0	500	346	0
0.6	1120	963.2	100	0	500	520	0	100	0	500	363.2	0
0.7	1140	980.4	100	0	500	540	0	100	0	500	380.4	0
0.8	1160	997.6	100	0	500	560	0	100	0	500	397.6	0
0.9	1180	1014.8	100	0	500	580	0	100	0	500	414.8	0
1	1200	1032	100	0	500	580	20	100	0	500	432	0

Table 8.1:- Results of fuzzy linear programming

8.4.2.3. Solution

In this chapter , the method of Verdegay (1982) is applied to solve the fuzzy linear programming model. The general model of linear programming with fuzzy resources is formulated as:

$$\text{Max} = c\chi$$

$$\text{s.t} \quad (A\chi)_i \leq b_i, \quad i = 1,2\ldots.m \tag{14}$$

Verdegay (1982) considered that if the membership functions of the fuzzy constraints are continuous, then Eq.(14) is equivalent of Eq.(15). Then it is equivalent to parametric programming, while $\theta = 1- \alpha$. Besides, p_i is the maximum tolerance from b_i and determined by decision maker. Therefore, the fuzzy linear programming problem given by Eq. (15) is equivalent to crisp linear programming model.

$$\text{Max} = c\chi$$

$$\text{s.t} \quad (A\chi)_i \leq b_i + (1-\alpha)p_i \quad \forall i,$$

$$\chi \geq 0 \text{ and } \alpha \ \varepsilon[0, 1] \tag{15}$$

The formulation of the case study is written in this section. The α_1 = 4/7 and α_2 = 3/7. They interpreted that there are seven criteria which consist of four internal criteria and three external ones. In addition, in the previous section we calculated total weighted value of internal and external criteria by SWOT analysis. These results are utilized as input data.

The manufacturer is working with supplier 1 for a long time. Moreover, supplier 1 is one of the key suppliers for automobile components. According to the strategic view point, the company prefers to buy at least 100 units of product 1 and 100 units of product 2 from supplier 1. This preference is taken into account by two constraints. In addition, according to the previous statistics, it is supposed that p_1 = 200 and p_2 = 172. This problem can be solved by using of Solver in Microsoft Excel. The solver of Excel is a suitable package for solving linear programming models. Besides, using of this software is easy for practitioners. The results of the proposed model are illustrated in Table 8.1. It can be inferred from the Table that the company purchases products from suppliers 1, 3 and 4. The only exception is for h = 1 that the company have to purchase from suppliers 1, 3, 4, and 5.

$$\text{Max} \quad (4/7) \times 0.795\chi_{11} + 0.631\chi_{12} + 1\chi_{13} + 0.841\chi_{14} + 0.728\chi_{15} + 0.769\chi_{21} + 0.626\chi_{22} + 0.987\chi_{23} + 0.871\chi_{24} + 0.745\chi_{25}) + (3/7) \times (0.626\chi_{11} + 0.639\chi_{12} + 0.966\chi_{13} + 0.778\chi_{14} + 0.727\chi_{15} + 0.626\chi_{21} + 0.639\chi_{22} + 0.966\chi_{23} + 0.778\chi_{24} + 0.727\chi_{25})$$

$$\text{s.t} \quad g_1(\chi) = \chi_{11}+\chi_{12}+\chi_{13}+\chi_{14}+\chi_{15} = 1000 + 200\,\theta$$

$$g_2(\chi) = \chi_{21}+\chi_{22}+\chi_{23}+\chi_{24}+\chi_{25} = 860 + 172\,\theta$$

$$\chi_{11} \geq 200,\ \chi_{21} \leq 250,\ \chi_{11} \leq 100,\ \chi_{21} \geq 100,\ \chi_{22} \leq 400,\ \chi_{12} \leq 100,\ \chi_{13} \leq 500,\ \chi_{23} \leq 500,\ \chi_{14} \leq 580,$$

$\chi_{24} \leq 650$, $\chi_{15} \leq 800$, $\chi_{25} \leq 800$.

$$4 \times (\chi_{11}+\chi_{12}+\chi_{13}+\chi_{14}+\chi_{15}) + 6 \times (\chi_{21}+\chi_{22}+\chi_{23}+\chi_{24}+\chi_{25}) \leq 11500$$

$\chi_{ij} \geq 0$, i =1,2, j = 1,2,3,4,5

8.5. Discussion

Suppose that the manager of supplier A1 has revised his policy and he has paid attention to the International communication (E3) as a critical factor. We want to examine the effects of this decision on the market and analyze the changes for the product 1. Therefore, three decision makers devote fuzzy numbers to this criterion for the supplier A1. By fixing other information, the problem has been resolved and the results have been written in Table 8.2. In addition, the matrix of SWOT has been shown in Fig. 8.5. It can be inferred from the figure that not only the situation of supplier A1 has been altered in the competitive market, but also it makes change the condition of other suppliers particularly supplier A4. Because supplier A4 had received the highest score. However, the score of supplier A1 increased and became the highest score. Considering the dynamic and competitive environment is the most important advantages of this method.

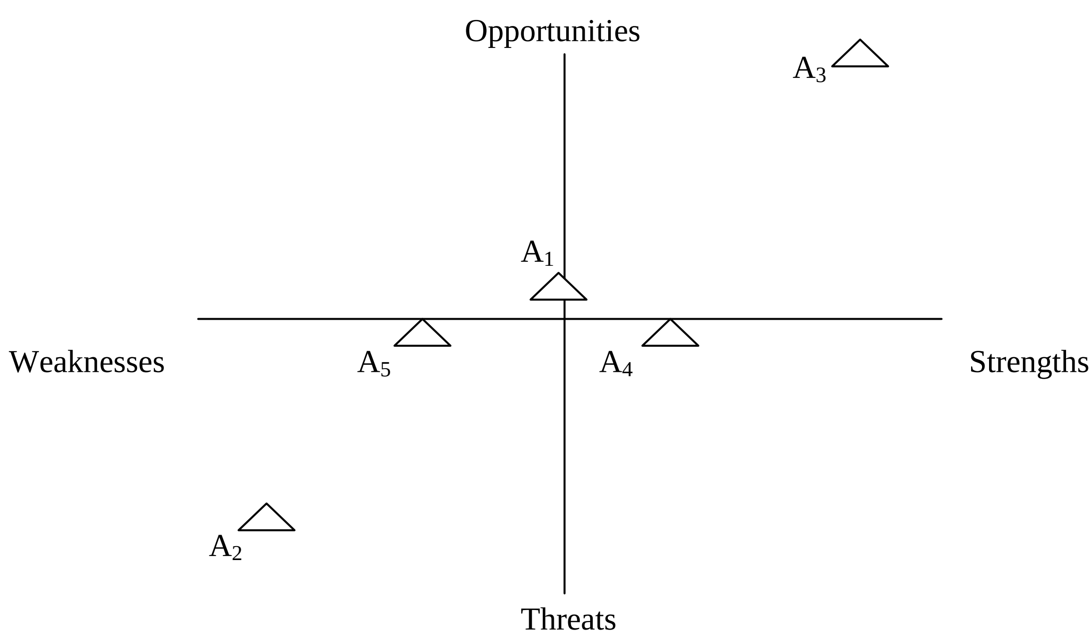

Fig 8.5:- Revised matrix of the SWOT analysis

Suppliers →	A_1	A_2	A_3	A_4	A_5
Internal total weighted value for product 1	0.795	0.631	1.000	0.841	0.728
Internal coordinated value for product 1 (x-axis)	-0.004	-0.168	0.201	0.042	- 0.071
External total weighted value for product 1	0.781	0.626	0.946	0.763	0.714
External coordinated value for product 1 (y-axis)	0.015	- 0.142	0.178	- 0.004	- 0.054

Table 8.2:- Revised coordinated value of suppliers under the SWOT analysis for product 1

Chapter 9

Publications

1) KAUSHAL.A, AGRAWAL.V.P "Structural modeling and integrative analysis of supply chain using systems approaches "International Journal of Physical Distribution and Logistics EMERALD Publishing house(Under review).
2) KAUSHAL.A, AGRAWAL.V.P "Selection of supply chain strategy based on risk and customer sensitivity dimensions by systems approaches" International Journal of Physical Distribution and Logistics EMERALD Publishing house (Under process).
3) KAUSHAL.A, AGRAWAL.V.P "A review of influence of ICT on Supply Chain Management and Performance" International Journal of Supply chain Management EMERALD Publishing house (Under review by Supervisor)
4) KAUSHAL.A, AGRAWAL.V.P "Performance measurement of the after-sales service network—evidence from the automotive industry" (Under review by Supervisor).
5) KAUSHAL.A, AGRAWAL.V.P "Concurrent design of a Supply Chain network for X-abilities using MADM approach" (Under review by Supervisor)
6) KAUSHAL.A, AGRAWAL.V.P "Supplier selection and order allocation based on Fuzzy SWOT analysis and Fuzzy linear programming" (Under review by Supervisor)
7) KAUSHAL.A, AGRAWALV.P. "A new way of literature review of approaches used for modeling and analysis of supply chains" (Under review by Supervisor)

Chapter 10

Conclusions

The methodologies given in this thesis builds a flexible and comprehensive model, which has the capability to consider the interdependencies between various subsystems of the total supply chain system:

1. The supply chain system permanent function is a mathematical model characterizing the structure of the supply chain system uniquely and identifying various structural patterns identifying various structural patterns and thus helping in the systematic structural analysis of the total supply chain system. The tool can support the concurrent design of supply chain system, by providing means of appropriate evaluation and decision tools. The structural analysis may aid in reviving the sick industrial units by aiding the problem identification and giving means of deciding the remedial actions. The BPR concept can make use of this methodology as an aid to systematically carry out its activities. Also, the model may act as an effective means of communication for conveying the information related to total design of the supply chain system.

2. The numerical index based on the permanent multinomial may act as a powerful tool in comparing, ranking and selecting appropriate supply chain system structure from various alternatives available and shall be useful aid in the vital area of benchmarking. It can provide "what if" scenarios for the manufacturer for the analysis of complex business decisions and act as a decision-support system.

3. The model may serve as a framework for developing various quantitative performance indices in various dimensions of performance, viz. responsiveness, agility, proactivity, flexibility, etc. giving a composite measure of the overall performance of the supply chain system.

4. The coefficient of similarity as well as dissimilarity developed may act as useful analytical tool for comparison of different structural designs of supply chain systems. Different alternative structures may be compared, ranked and finally selected for system wide optimization.

5. The limitation of lack of visibility on other portions of the supply chain system can be overcome by this comprehensive and flexible model as it can consider all structural elements of the supply chain system in totality. The important subsystems of humans, environment and the interactions thereof are taken into account in an integrated manner.

6. Proper procedures and guidelines may be developed for assigning appropriate numerical scores for various variables of the supply chain systems thereby aiding the experts to quantify

their opinion. This may tend to eliminate the inherent human variations erupting due to these expert opinions. Even a knowledge-based system may be developed by converting the expert's thoughts into rule-based knowledge system. This development may help to quickly assign the numerical scores and thus can enhance the usefulness of the methodology:-

To assist industries in designing, developing and managing an effective and efficient SCM system

The following contributions are highlighted:-

1. Hierarchical tree structure and integrative block diagram of SCM system permits to develop in depth understanding of every subsystem and issue of the system in totality.

2. Mathematically models make every subsystem and interrelationships between subsystems as variable. This helps decision makers to study all the performance parameters and subsystems leading to improvement.

3. The methodology permits to generate alternative designs/structures of the SCM system at the conceptual stage and purchase or hire off the shelf subsystems from the global market. This helps in developing and installing an effective and optimum SCM system in shortest possible time for a given application.

4. The methodology permits to develop a comprehensive database of SCM system available commercially in global market

5. Coefficients of similarity and dissimilarity allow comparing different alternative solutions of SCM and selecting the best one.

6. Step by step procedure is designed to assist the users and industries to implement the methodology in an efficient way.

7. Usefulness highlights the need and application by decision makers.

8. The application of graph theory and matrix algebra widens the scope and importance of the developed methodology

9. Designing an optimum supply chain network is important in order to achieve desired functionality. This requires best possible network element to put in use considering all x-abilities.

10. After specifying network objectives and considering application requirements of users, design of a supply chain network starts with identifying pertinent attribute concurrently for each x-ability viz. performance, resilience, security, maintainability, etc. by different team of experts considering technological and infrastructure standards, specifications, features and constraints. Design teams then uses these pertinent attributes to select specification of technology and

network elements with their relative importance using fishbone diagram. All the specifications selected by different teams individually for each x-ability are integrated maintaining their relative importance. TOPSIS technique, MADM approach, is used for selection of best possible network elements based on relative importance of specifications of network elements.

11. This design for x-abilities enable the industry designers to focus on various abilities at conceptual design stage on one hand and concurrent design approach helps reduce design time and product cycle considerably on the other hand.

12. This methodology finds usefulness in design of various other products/services that has different attributes/features/quality standards/performance requirements.

13. Comparison of existing design procedures with the proposed one is made.

14. Fishbone diagram uses various attributes identified concurrently for each x-ability. These design steps consider all relevant x-abilities of supply chain network from the initial design phase itself that helps reduce design time considerably. Thus a concurrent design methodology for design of supply chain network for x-abilities using MADM approach is accomplished.

15. Supplier selection is a multi criteria decision-making problem, which includes both qualitative and quantitative factors. In this chapter, we have proposed a decisional model for supplier selection which consists of two phases. In the first phase, quantified SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) is applied for evaluating suppliers. The linguistic variables and triangular fuzzy numbers are used to quantify variables. In the second phase, a fuzzy linear programming model is applied to determine the order quantity. The major novel points and merits of the proposed model are in fivefold: first, the model analyzes the supplier selection problem from strategic view point. Second, fuzzy logic has been applied because it can take into account uncertainty in humans' opinions. Besides, it is assumed that demand is a fuzzy number. Third, fuzzy logic and quantitative SWOT have been composed for the first time. Fourth, both of quantitative and qualitative factors have been considered. Fifth, the capacity of warehouse and minimum order quantity are taken into account as constraints in the mathematical model. This algorithm can be easily implemented with a spreadsheet package and its computation is fast. Therefore, the proposed model can be applied easily in practical situations. Not only the proposed fuzzy SWOT analysis can be applied for evaluating suppliers, but also it can be utilized for what De Boer et al. (2001) stated as a pre-qualification of suitable suppliers. The pre qualification is defined as the process of reducing the set of all suppliers to a smaller set of acceptable ones. After drawing a quantified SWOT matrix, the manager of company can choose a pool of suppliers from the first quadrant of SWOT matrix. In the case study, suppliers A3 and A4 would be selected. Expertise, experience, authority, and the responsibilities of decision makers are not equal in practice. Further research may be the determination of DMs, weights. Furthermore, in the mathematical model, the weights of internal

and external criteria are determined by decision makers. It is useful to propose a scientific method for determining these weights. In addition, this chapter has focused on manufacturing environment. It is worthwhile to implement fuzzy SWOT to select suppliers in service industries and compare the results. Moreover, we assumed that demand is a fuzzy number. Another future research may be the proposing mathematical model with stochastic and robust parameters.

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