PERFORMANCE IMPROVEMENT OF AN AUTOMOBILE INDUSTRY USING SUPPLY AND DEMAND CHAIN MANAGEMENT

THESIS SUBMITTED BY

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CERTIFICATE FROM THE SUPERVISORS

This is to certify that the thesis entitled "**Performance Improvement of an Automobile Industry using Supply and Demand Chain Management**" submitted by **Sri K. Balakannan**, who got his name registered on **31st December 2014** for the award of Ph.D. (Engineering) degree of Jadavpur University is absolutely based upon his own work under the supervision of Dr. Partha Sarathi Chakraborty, Dr. S. Nallusamy and Prof. Gautam Majumdar and that neither his thesis nor any part of the thesis has been submitted for any degree / diploma or any other academic award anywhere before.

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4. S. Nallusamy, K. Balakannan, R. Suganthini Rekha, K. Balasubramanian, "A review on valuable trends of product data management occupied in new product development", **International Conference on Applications and Design in Mechanical Engineering** at The School of Mechatronics Engineering, Universiti Malaysia Perlis, Penang, Malaysia, 30-31 March 2015

DEDICATED TO MY BELOVED PARENTS

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- K. Balakannan

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LIST OF ABBREVIATIONS

AHP	-Analytic Hierarchy Process
ANN	-Artificial Neural Network
ANP	-Analytic Network Process
CFI	-Comparative Fit Index
DCM	-Demand Chain Management
DEA	-Data Envelopment Analysis
DSS	-Decision Support System
EIA	-Environmental Impact Assessment
EII	-Environmental Impact Index
EMS	-Environment Management System
ESI	-Environmental Sustainability Index
FANP	-Fuzzy Analysis Network Process
FLDMM	-Fuzzy Logic Decision Making Method
FMOLP	-Fuzzy Multi-Objective Linear Programming
FMS	-Flexible Manufacturing System
FSIR	-Fuzzy Superiority and Inferiority Ranking
FST	-Fuzzy Set Theory
GA	-Genetic Algorithm
GM	-Green Manufacturing
GSC	-Global Supply Chain

LIST OF ABBREVIATIONS (Continued)

GSCM	-Green Supply Chain Management
GSCND	-Global Supply Chain Network Design
INLP	-Integer Non-Linear Programming
ISP	-Indicators for Sustainable Production
LG	-Lean Green
LMP	-lean manufacturing practices
LMS	-Lean Manufacturing System
MCDM	-Multi - Criteria Decision Making
MILP	-Mixed-Integer Linear Programming
MPT	-Mathematical Programming Techniques
NAFTA	-North American Free Trade Agreement
NFI	-Normed Fit Index
NNFI	-Non-Normed Fit Index
OEM	-Original Equipment Manufacturer
PSE	-Process System Engineering
PSO	-Particle swarm optimization
RFID	-Radio frequency identification
RL	-Reverse Logistics
RMSEA	-Root Mean Square Error of Approximation
RMSEA	-Root Mean Square Error of Approximation

LIST OF ABBREVIATIONS (Continued)

SCM	-Supply chain management
SCND	-Supply Chain Network Design
SCOR	-Supply Chain Operation Reference
SEA	-Strategic Environmental Assessment
SMED	-Single-Minute Exchange of Die
SME	-Small and Medium Enterprises
SMM	-Supplier Maintained Machines
SSCM	-Sustainable Supply Chain Management
TBL	-Triple Bottom Line
VNS	-Variable Neighborhood Search

ABSTRACT

In this era of globalization and fluctuating markets, supply chain management has gained more significance among the corporate. Supply chain management is an important activity in manufacturing which influences product life cycles, price levels, delivery schedule, customer satisfaction, inventory etc., Supply chain management integrates all key business activities through improved relationship at all levels of supply chain.

In the present scheme of things, in a manufacturing industry inventory is pitched as one of the predominant resources that require to be handled effectively. The aim of the first section of the research was to develop a mixed- integer linear programming model to configure the closed loop supply chain (CLSC) network that could be optimized for maximizing the profit by determining the fixed order quantity inventory policy in various sites at multiple periods. In onward supply chain, a standard inventory policy could be followed when the product moves from manufacturer to end user, but it is very difficult to manage the inventory in the reverse supply chain of the product with the same standard policy. The proposed model examines the standard policy of fixed order quantity by considering three major types of return-recovery pair such as, commercial returns, end-of-use returns, end-of-life returns and their inventory positioning at multiple periods. Raw material supplier, manufacturer, distributer, retailer, customers and for major returns-collection sites like repair site, disassembly site, recycling site and disposal site were included in the network to develop this CLSC network model. The objective of this section was to maximize the profit through CLSC by determining the optimal inventory of product and part mix during multiple periods. The proposed model to configure the CLSC network was solved by using IBM ILOG CPLEX OPL studio and the results of the model were analysed with numerical investigations followed by sensitivity analysis.

In universal spirited environment, automotive industries are desired to perform efficiently to meet the maximum percentage of demand by minimum cost. The objective of the second section of the research section was to create a balance scorecard model for the evaluation of reliability and performance of automotive manufacturing industries to evaluate their supply and demand chain system. Using this new idea, the performance of industries could be assessed regarding their supply and demand chain system with the major four criteria like design and development, manufacturing point, financial requirement and consumer's point of view. The main four features of the industries are policies and firm coordination, design and execution, effectiveness of shipment and information technology usage totally covered by the new designed balanced scorecard with twenty five evaluation points. A broad survey was carried out in Indian automotive manufacturing industries with well structured questionnaires to collect the necessary data. The comparison between multinational, public limited, private limited and small scale organizations were carried out to measure the performance variation of their supply and demand chain system. Based on the correlation of the above four features, a structural equation model was designed to improve the supply and demand chain management system for automotive manufacturing industries and found that the 'α' coefficient was above 0.80, hence, the balanced score card was taken as reliable.

The third section of the research was to study the application of Fuzzy AHP method for evaluating Green supply chain management strategies for automobile manufacturing company. The strategies were calculated by the model of Fuzzy AHP, the main attributes, sub attributes and measurement indicators were defined based on the automobile manufacturing process.

The fourth section of the study deals with the selection of suppliers. Traditionally in Supply chain management, the key focus and scope has been on managing the flow of materials and goods from suppliers through manufacturing and distribution chain to the customer. The idea of demand chain management is based on the principle of using demand instead of supply as the factor integrating the information needs in the supply chain. The key in demand chain management is the continuous flow of the demand information from customers and end users through distribution and manufacturing to suppliers. The shared objective of the chain is fulfilling of customer demand. The most important controlling inputs are rolling forecasts and plans, point-of-sales data, daily orders, management decisions and performance feedback.

The final section of the research was on the green supply chain management which is the basic tool for integration of raw materials procurement, production handling and material distribution. The added benefits of this process is effective management capacity, accuracy in demand forecasting and enhanced delivery performance by making the supply chain more sustainable and effective. The organizations should adopt ecological balance, eco-friendly strategies for the establishment of harmonic supply chain management. Already various investigations have been done and theoretical and empirical models developed in the field of supply chain management. The results of the study revealed that "green manufacturing” share to be the most worthwhile attribute in the present Green supply chain management strategy.

The overall objective of this research on the supply and demand chain performance parameters has been made with a view on green manufacturing in an automobile industry. From the convincing studies conducted, the results were evaluated and various suggestions were presented for improvement.

1.0 Introduction

1.1 Introduction about SCM and DCM:

Present scenario reveals that, manufacturing industries are forced to focus on the ability to respond quickly to the changing market demand during next decade. This fact has arisen on effect of global competition, shortened product life cycle, shortened delivery time, lower product price, complex and variety of product demand from the customers. The focus from the concept of mass assembly is shifting towards mass customization. During the last few decades market has metamorphosed from the 1970s cost concern to quality concern. Now product customization with speed of the delivery has added a new dimension in manufacturing industry.

Supply chain management and logistics management make sure that manufacturing goods reach customers with right quality in right time and at right quantity through the necessary channel. SCM contracts with meeting the required demand using material supply while, LM guaranteed the progress of the goods from the point of supply to the demand. The aim of any supply chain and logistics management resolutions is to assure that a manufactured item reduces the end customer at the minimum possible cost [**Birhanu, D. (26)** and **Gandhi, A. (76)**]. Many ongoing research projects in supply chain and logistics management are in progress for the past few decades to attain this objective but more often than not in a conventional supply chain network setup, where the network split ends at a physical retail shop. The start of e-commerce has changed the way of supply chain and logistics management decisions. The day is not far off when the majority of the material retail shops would be forced to lock due to their lack of ability to contend in cost with the e-commerce canal. Even though there is high revenue making through online sales, there is still more work that requires to be carried out to minimize the cost of the product. The assessment of the performance of supply chain and logistics management steps over individual business limits, thus it is essential to provide entire deliberation to function circumstances within the whole supply chain system which basically increases the complexity. Supply chain and logistics performance management evaluation has become a significant division of supply and demand chain management which has kindled the awareness of various national and international research scholars. In this research various parameters have been analysed, performance variation measurement of supply chain and logistics management with a structured balanced scorecard model being one among them. Enormous scholarly research articles have been already published in the area of supply chain and logistics management. A standard review of key survey articles across various aspects of supply and demand chain with logistics management that facilitates the reader with a preliminary tip to continue the research has been attempted. A SCM policy defines the business model for operating a supply chain to place an organization in the competitive market. Every manufacturing unit has its own supply chain strategy and the aim is to make sure there is the increase of income with decrease of cost [**Balakannan et. al. (21)** and **Khodakarami et. al. (118)**].

Supply chain management (SCM) is the key hub and the main objective is managing the flow of materials and goods from suppliers through manufacturing and distribution chain to the customer. Important considerations are, materials requirement planning, capacity management, production planning and scheduling, inventory levels and supply allocations [**Korhonen et al. (123)**].

Demand chain management (DCM) is the continuous flow of the demand information from customers and end users through distribution and manufacturing to suppliers. The idea of DCM is based on the principle of using demand instead of supply as the factor integrating the information needs in the supply chain [**Vollman**

(248)].The shared objective of the chain is in fulfilling customer demand. The most important controlling inputs are, rolling forecasts and plans, point-of-sales data, daily orders, management decisions and performance feedback [**Korhonen et al. (123)**].

"The main difference between SCM and DCM is nothing but the focus and starting point of planning and controlling: In SCM, it is the material supply push and in DCM, it is the user demand pull" [**Korhonen et al. (123)**].

SCM views materials flow from supplier to manufacturer, distributors and finally to customer based on the forecasts and orders as shown in Figure 1.1. In demand chain material pull is based on the orders on daily basis, considering sales information, product promotional offer, market trend etc as shown in Figure 1.2 and information flows from customer, distributor and manufacturer to suppliers.

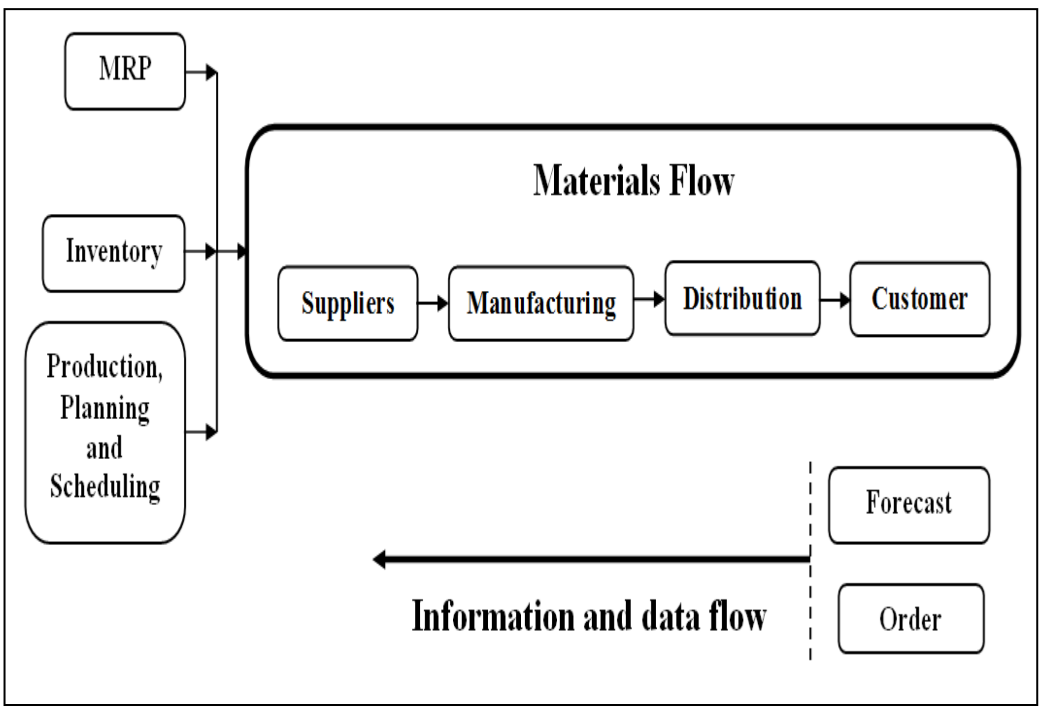

Figure 1.1: Supply Chain Management View

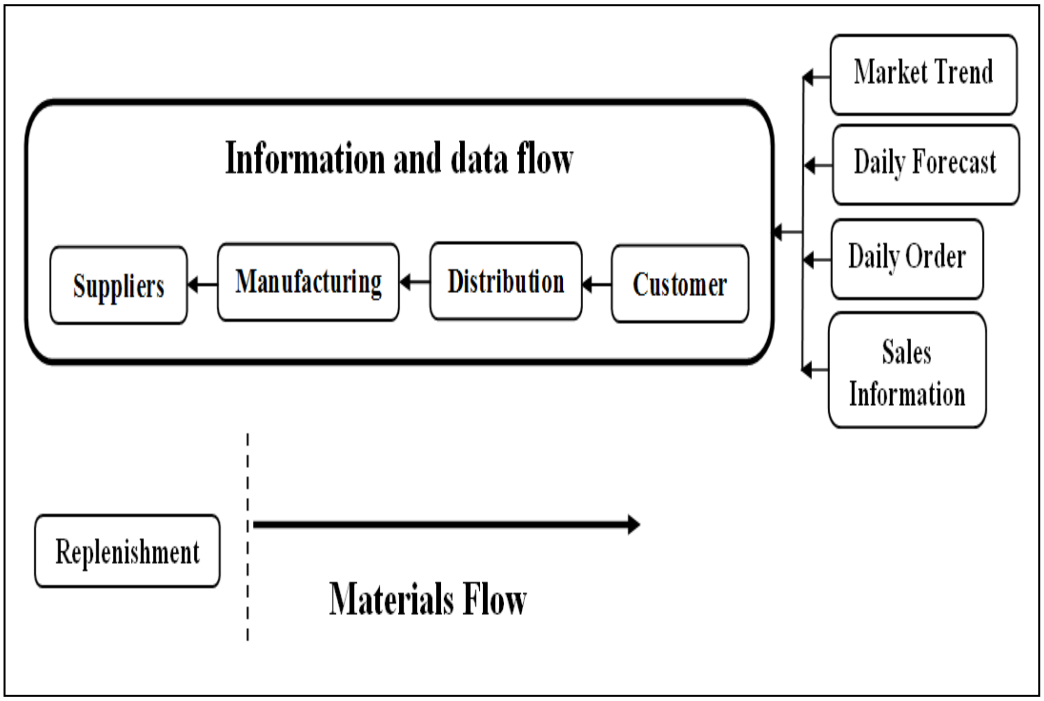

Figure1.2: Demand Chain Management View

Supply chain planning is done at three levels such as strategic, tactical and operational as shown in Figure 1.3. Strategic planning is at the top of the pyramid. Demand chain inputs to supply chain planning are provided to fine tune the supply network. The robust planning approach specifically addresses the physically efficient supply chains, at a tactical level. It is aimed at recognizing and exploring the uncertainty that is inherent in supply chains and distilling the planning decisions that will yield more predictable and stable results. Figure 1.4 shows deterministic approaches yield one “optimal” plan for a deterministic value for each variable, while robust planning provides a “near optimal” solution, which stays valid for a range of variable values at a predictable but higher cost [**Landeghem and Vanmaele (129)**].

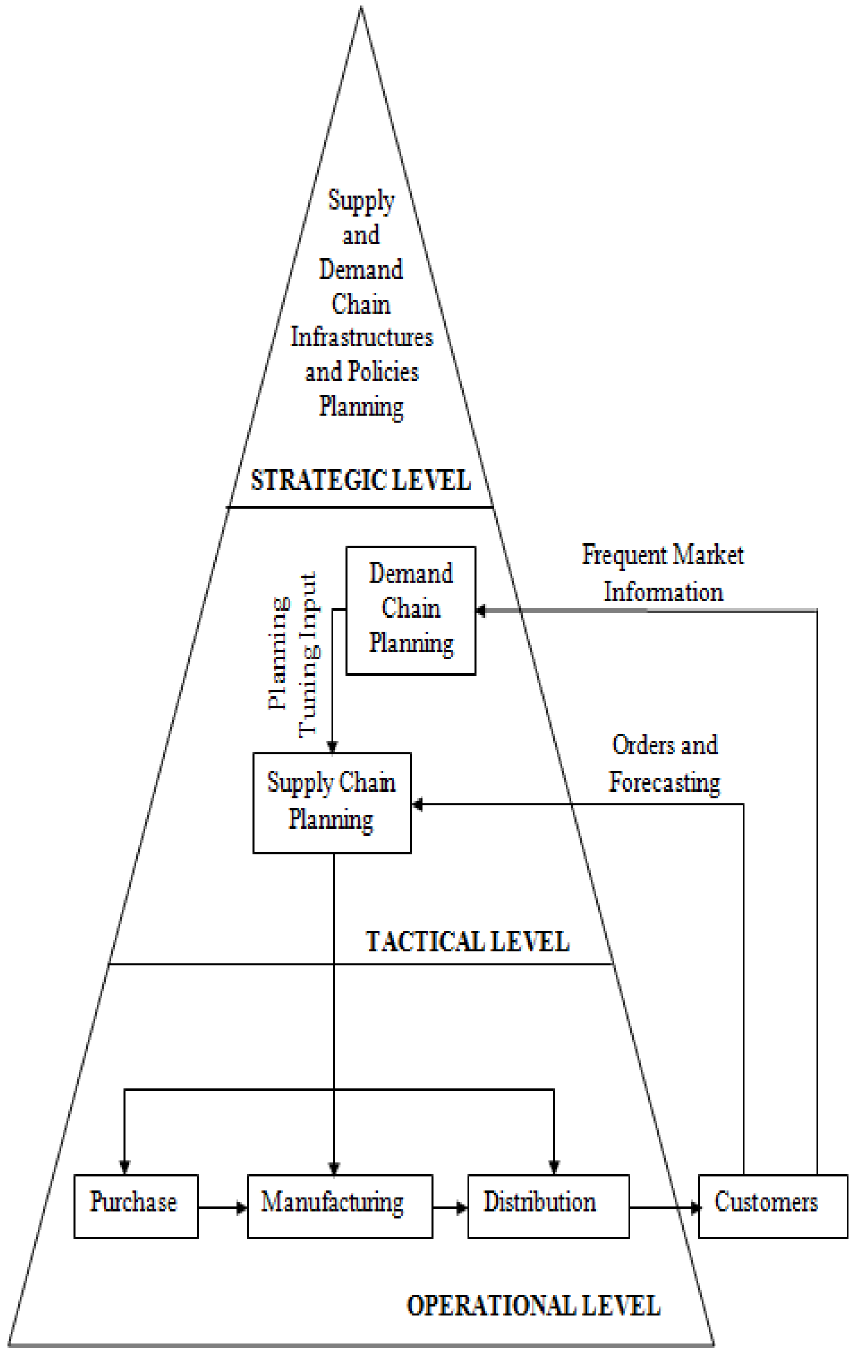

Figure 1.3: Supply and Demand Chain Planning for an Organization

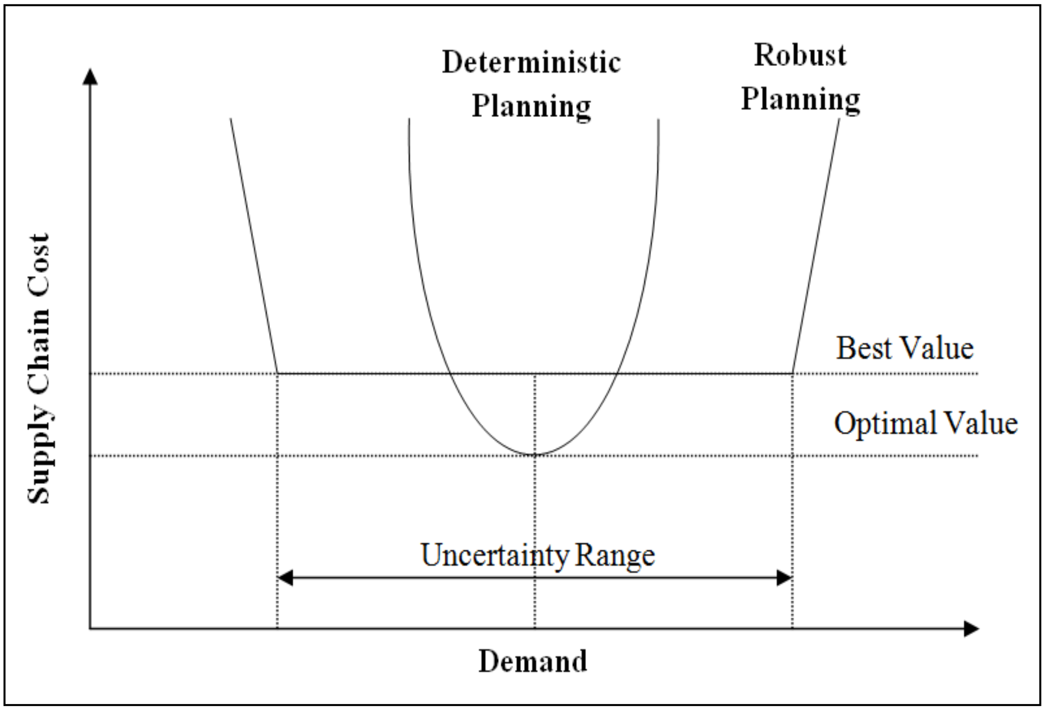

Figure 1.4: The Effect of Robust Planning on Total Supply Chain Cost
[**Landeghem (129)**]

1.2 Supply Chain Management:

A supply chain consists of all stages involved directly or indirectly in fulfilling a customer demand. SCM includes managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracing, order entry and order management, distribution across all channels and delivery to the customer. Due to this wide nature of scope, supply chain has to address complex interdependencies. Meeting customers' specific demands for product delivery has emerged as the next critical opportunity for competitive advantage. To meet the ever rising customer expectations at a manageable cost, organization must identify which parts of their supply chain process are not competitive. Then establish improvement goals and rapidly implement necessary improvements. SCM initiatives have exposed the true cost of traditional built for stock approaches. Organizations till now have not been able to find a standard common tool to measure supply chain performance.

SCM initiative started in 1990's gained momentum shortly and has now become widely acknowledged. Manufacturing competitiveness in this global village has compelled supply chain partners of the giant corporations in the manufacturing, retail and service sectors to bring down the price, which has affected supplier-manufacturer relationship. Supply chain visibility and good response time are impossible to meet without good supplier manufacturer relation. Economic instability, higher customer demand, excess inventory, supplier manufacturer relationship is more important than ever before. Today leading organizations are selecting the trading partners carefully and working with them collaboratively to survive. Organizations focusing internal improvements through cost reduction gain benefits, but are way behind the bottom line gains recorded by the organizations working collaboratively with their trading partners. On the other hand some organizations started working a lot to improve internally and also started collaborating with selected number of trading partners. They are moving towards the advanced stage of supply chain management. Supply chain may be lean, agile or leagile mainly depending upon the type of products and management philosophy. Combination of agility and leanness in one supply chain via the strategic use of a de-coupling point has been termed 'le-agility' [**Naylor et al. (172)**]. The comparison of attributes on three types of supply chains as lean, agile and leagile is given in the following Table 1.1.

Table 1.1: Comparison of Lean, Agile and Leagile Supply Chain

Attributes	**Lean supply chain**	**Agile supply chain**	**Leagile supply chain**
Market demand	Predictable	Volatile	Volatile and unpredictable
Product variety	Low	High	Medium
Product life cycle	Long	Short	Short
Customer drivers	Cost	Lead-time and availability	Service level
Profit margin	Low	High	Moderate
Dominant costs	Physical costs	Marketability costs	Both
Stock out penalties	Long term contractual	Immediate and volatile	No place for stock out
Purchasing policy	Buy goods	Assign capacity	Vendor managed inventory
Information enrichment	Highly desirable	Obligatory	Essential
Forecast mechanism	Algorithmic	Consultative	Both/ either
Typical products	Commodities	Fashion goods	Product as per customer demand
Lead time compression	Essential	Essential	Desirable
Eliminate waste	Essential	Desirable	Arbitrary
Rapid reconfiguration	Desirable	Essential	Essential
Robustness	Arbitrary	Essential	Desirable
Quality	Market qualifier	Market qualifier	Market qualifier
Cost	Market winner	Market qualifier	Market winner
Lead time	Market qualifier	Market qualifier	Market qualifier
Service level	Market qualifier	Market winner	Market winner

[**Mason-Jones et. al. (146), Naylor et. al. (172), Bruce et. al. (29), Olhager (175)** and **Agarwal et. al. (2)**]

1.2.1 Limitations of Supply Chain Management:

If real demand data, pushed back upstream as far as possible, can be used to dampen 'bullwhip effect' of inventory creation. This implies that the total chain can operate with fewer inventories. In demand chain planning with proper production and logistics systems, actual pull type demand is used rather than forecast based supply to drive material flow. In present scenario, organizations are under extreme pressure to respond faster and faster to the customer. Shortening logistics lead time has become a major challenge in demand chain design. Demand driven processes gain ground over supply driven processes due to competitive market demand of responsiveness and flexibility.

1.2.2 Lean Supply Chain:

To optimize the lean supply chain, partnership building with suppliers is essential, considering them as any other department of the organization. This partnership will be based on mutual benefit and trust, and also with the understanding that materials will be supplied as and when required i.e. replacement of consumed quantity only. Suppliers are to be involved in strategic planning. Two way agreements may also be explored if required.

1.2.3 Lean Manufacturing to Lean Supply Chain:

Lean focuses on eliminating non value added activities and streamlining value added activities to increase operational efficiencies. Lean works well in supply chain, where waste can hamper the overall productivity and profit of the partners. Many organizations consider supply chain initiatives as cost cutting or technology implementation exercise. But supply chain management goes far beyond the four walls of the organization, actually begins with needs of customers and ends with the needs of consumers.

1.2.4 Top Ten Supply Chain Errors: [Sengupta (210)]

1. Believing that supply chain management is about managing a chain.
2. Trying to achieve major changes while doing business as usual.
3. Having unshakable faith in the value of vertical integration.
4. Failing to synchronize demand chains and supply chains.
5. Talking about transformation in terms of the enabling technology.
6. Pursuing "real time" visibility at all costs.
7. Practicing supply chain "monotheism".
8. Misreading employees' skill and aptitudes.
9. Confusing globalization with global brands and cross border trade.
10. Thinking that supply chain transformation is a simple task.

Due to the advancement of Information technology, now it is possible to integrate purchasing, manufacturing and distribution activities scattered around the globe, which ultimately has reduced the supply chain movement time. Very little progress have been made in the supply chain capabilities Organizations spend money on off-the-shelf packages but what is requires is to make the necessary process changes first, then only technology can be exploited properly. Supply chain management includes all supply chain planning, collaboration and execution application. Supplier management, supplier development supplier consolidation, information technology hardware, software are critical basic steps towards the implementation of SCM. Technology like Radio frequency identification (RFID) is important to identify goods as they move through the stages.

1.2.5 Supply chain support from non supply groups: [Trent (238)]

Engineering: Evaluate technical capabilities during supplier site visit and interact with supply managers during product development.

Marketing: Develop accurate and timely demand requirement and share end-customer requirements with supply chain planning groups.

Finance: Validate cost savings from supply chain activities, identify the impact of supply chain initiatives on corporate performance indicators, including ROI and RONA and also assess the impact of inventory improvements on cash flow and working capital requirements

Accounting: Provide accurate data to support internal and external cost analysis

Information technology: Support the development of supply chain information systems, including performance management system.

Human resources: Support the recruitment of human resources to staff supply chain positions and provide training and education programmes related to supply chain knowledge and skill areas.

Legal: Perform timely and effective reviews of supply chain contracts.

1.2.6 Objective of Supply Chain: [Chopra and Meindl (51)]

The objective of every supply chain is to maximize the overall value generated. The value a supply chain generates is the difference between what the final product is worth to the customer and the effort the supply chain expends in filling the customer's request.

1.3 Demand Chain Management:

It is the involvement of 'chain' of entities such as employees, resellers, partners, etc. and activities as campaigns, programs, tactics, etc. are used to create demand and also convert this demand to sale of the products, and services.

The Demand Chain involves all activities directly or indirectly to market, sell, distribute, and service products. Synchronizing these customer facing processes with manufacturing operations using frequent forecast facilitates the actual demanded material flow. Integration of demand-driven customer-facing processes with supply chain leads to increased profitability.

Demand chain management planning leads to:

1. Higher customer service levels.
2. Higher inventory turnover.
3. Higher capacity utilization.
4. Lower cost of goods sold.

Demand chain management can be made more effective by:

1. Effectively capturing, interpreting, and fulfilling orders.
2. Reduce the number of stops and expedite transportation of finished goods.
3. Optimize ways to generate and fulfill customer demand.

While forecasting demand and replenishment, functional and innovative product approaches are different. New products fall into the innovative group and require very responsive forecasting and replenishment approaches.

Inaccurate demand forecast can unsettle the supply and demand chain leaders. In 2000 Cisco entered into a long term contract with the key suppliers to meet the high demand, but end of that year suddenly market experienced a recession, but its suppliers were unable to adjust fast. Ultimately Cisco ended up with a inventory write off of $2.5 billion in April 2001. With newer forecasting tools and contractual arrangement the problem can be reduced.

Now various organizations have started to synchronize their supply chain with actual demand, not the forecasted demand. By introducing true demand these companies have started to transform their supply chain to demand chain.

Following three actions can help in this transformation:

1. Focus on actual demand of the customer.
2. Flexibility of supply chain
3. Integrate suppliers and parent organizations supply chain.

1.4 Effectiveness:

The term effectiveness is used to describe how well the outputs achieve the desired goals; how much results are obtained because of the outputs. Measuring of effectiveness should be delineated prior to the identification of outputs in that, until such measures are established, one can hardly identify what to count as outputs and how to count them [**Mundel (155)**].

Degree of effectiveness can be measured evaluating three criteria such as

1. Do the 'right' things according to the laid down specifications.
2. Get all the 'right' things done.
3. Doing all the right things on right time.

1.4.1 Relationship with Productivity:

Effectiveness, the output to achieve goal, is as important as productivity. If large quantities of unwanted output are produced, that will add to inflation. To achieve the desired results and, to arrest the inflation, productivity and effectiveness need to be improved simultaneously. The planning process is closely tied in with effectiveness. Sometimes the factors that improve effectiveness also improves productivity and vice versa. In some cases tradeoffs are made between productivity and effectiveness, though it is not easier to make than said [**Mundel (155)**].

1.4.2 Personal Effectiveness:

The competitive environment affecting industries create, effects on individual organizations, and which in turn propagates on jobs within the organization and also on the individuals doing those jobs as shown in Figure 5. Today's competitive scenario is forcing organizations for individual empowerment throughout the ranks to contribute towards the organization goals. This automatically implies every individual need to be equipped with more skills and tools for achieving effectiveness in job. Personal technical skills, intelligence does not guarantee personal effectiveness as these may not match with organization's mission and vision. Employees trained in personal effectiveness are better equipped to handle new situations, with confidence in their ability to be effective.

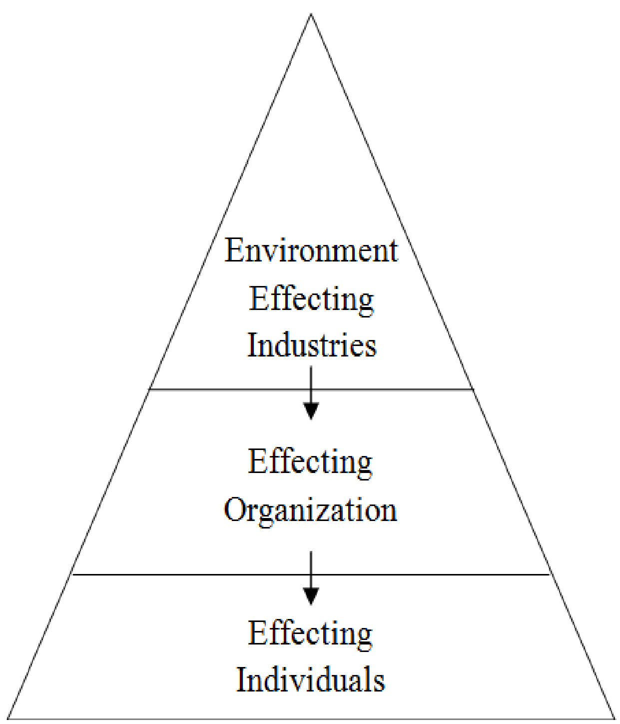

Figure 1.5: Flow of Competitive Scenario up to Individual Level

1.4.3 The Framework:

A four step framework for improving effectiveness:

1. How are things being done as well as they are supposed to be?
2. What was done well and less well in terms of effectiveness?
3. Activities need to be done to ensure or improve effectiveness.
4. Things can be learnt from others i.e. benchmarking with others.

1.4.4 Scope of Application:

Effectiveness has wider or smaller implacability as shown in Figure 6.

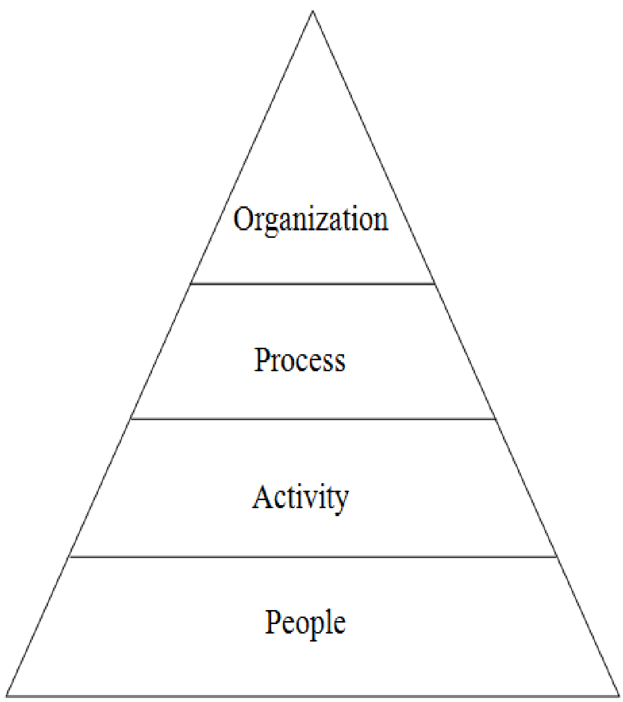

Figure1.6: Applicability of Effectiveness

1.5 Productivity:

Productivity is ratio of outputs generated from a system and the inputs provided to create those outputs from same base period. Inputs are in the form of labour, capital, material, energy and data. These are consumed to produce outputs that are goods, services. To improve productivity current status is to be measured first. Then the targets are fixed carefully for improvement.

Robert Solow, the Nobel Laureate economist, once quoted “We see computers everywhere except in the productivity statistics”. One of the core issues for economists in the past decade has been the productivity slowdown. With the advent of IT, office work has become capital intensive and approaching nearer to production work i.e. IT capital per office worker is approaching that of production capital per production worker. Management cannot access the process improvement efforts and impact for measuring productivity without some mechanism.

Productivity can be examined on the following areas.

1. Global
2. Regional
3. National
4. State or larger jurisdiction within a nation
5. Organizational
    a. Whole
    b. Business Division
    c. Particular area of a division
    d. Work centre

Almost all the productivity measurement models discussed in the following section falls in the organizational category.

1.5.1 Productivity Paradox:

Productivity and profitability are not always related proportionately. Increase in productivity will not lead to increase in profitability or in some cases profitability may increase by considerable amount, though productivity may not perform well.

Competitive market developed due to shorter product life cycle, technology change, and high customer aspiration level forces organization's manufacturing strategy to be lined with business strategy.

1.5.2 Productivity, Performance and Effectiveness:

The emphasis of effectiveness is on 'doing right things' and efficiency is 'doing things right'. The following example shows the differentiation between them.

Consider a case, where an operator can produce 200 parts in a machine in 8 hours. Then on sensing demand, the organization replaced the old machine with one automated machine which can produce 1000 parts, but market demand was 800 parts. Quality of the product also improved due to the automated machine, thus increasing effectiveness. Productivity also increased by 4 times, but performance had fallen by 20%.

1.5.3 Kinds of productivity measurement:

Productivity model depending on usage of outputs and inputs are

(a) **Single factor (partial) productivity**: It is the ratio of output to a single physical input (e.g. labour, capital, energy etc.). Single factor productivity measure is usually named after the input type consumed [**Mundel (155)**].

- Labour productivity: In this case resource inputs are aggregated in terms of labour hours, so this is independent of wage rate and labour mix.

- Direct labour cost productivity: In this case resource inputs are aggregated in terms of direct labour cost. This will reflect both changes in wage rate and changes in labour mix. Inflation effect needs to be minimized by deflating the value of currency to some constant datum.
- Capital productivity: Can be measured by considering the depreciated amount during that period as input or the book value of capital equipment used.
- Direct cost productivity: In this case all items of direct cost associated with resources used are aggregated on a monetary value basis. Inflation effect needs to be minimized by deflating the value of currency to some constant datum.
- Total cost productivity: Here all resource costs, including depreciation are aggregated on a monetary value basis. Inflation effect needs to be minimized by deflating the value of currency to some constant datum.
- Energy productivity: The units of energy consumed are considered as input.
- Raw material productivity: Here numerators are usually the weight of the product and denominators are either value or weight of the raw materials used.

Various other productivity indexes can be developed depending on the requirement.

(b) **Multifactor productivity**: It can be further divided into

- Total factor productivity: It is the ratio of value added output (excluding material) to the sum of labour and capital inputs.
- Total productivity: It is the ratio of output to the total inputs.

1.6 Reverse Logistics:

In a global competitive market, manufacturing industries are in the position to carry out professionally with minimum percentage of inventories, there-by reducing the cost of manufacturing. SCMplays an important role during the development of product, survival in the market, maximization of production rate and energetic contacts between the suppliers and customers. An efficient way of recapturing the value of a product and the proper disposal of material, the remanufacturing industries finds difficulty in the design of Reverse Logistics (RL). During last few years, the area of reverse logistics has been given more attention by many industries and academicians. Due to environmental impact and economic performance, there should be proper management to reverse the flows of products and parts to reduce the negative impact on the environment. This necessitates a proper mix of recovery options which is a great challenge in reverse supply chain. The options for the recovery of returned products consist of reuse, resale, repair, refurbishing, remanufacturing, cannibalization and recycling. Among recovery of product, repaired ones are collected in the collecting site and usable products are cleaned, refurbished, and transported to manufacturing site. In re-manufacturing and recycling process, used products are disassembled into parts in the disassembled site and transported back to the manufacturing site. Reverse logistics is a very vast field of study with various issues being addressed such as remanufacturing, commercial returns, end-of-life returns and so on.

The back bones of any Original Equipment Manufacturer (OEM) are the suppliers who are the major stakeholder of their supply chain. They have a main contribution in OEM’s quality of the product, delivery schedule, customer satisfaction, profitability and market competiveness. Thus suitable choice of supplier becomes an important decision making area in any business process. Proper selection of suppliers can considerably decrease production lead time, reduce manufacturing cost, increase customer satisfaction, and strengthen corporate competitiveness. Recent literature shows that OEM's now-a-day's aim to build long-term relationships with suppliers for sustainable business and purchase managers always face the challenges and difficulties.

While selecting the right suppliers, careful assessment is required because suppliers have their own strengths and weaknesses. The supplier selection would be straight forward if only one criterion is considered but in real situations range of criteria are adopted then the problem gets multi-criteria decision making. In multi-criteria decision making, a set of criteria depends upon the situation as adopted by the researcher. Problem on supplier selection and evaluation for specific situation means that all method related to supplier selection need not be applicable for all possible incidences. Often they assume, in all buying situations explicitly or implicitly, that their method is applicable at most, a method or procedure were applied to a particular industry for considered criterion, could not be applicable for a different industry. However, the existing articles on methods do not sufficiently address this contextual issue [De Boer Luitzen **et. al. (50)**].

Minimum three papers have been reviewed based on literature on supplier selection and evaluation models previously. **Chai Junyi (36)** reviewed the articles published from 2008 to 2012 by focusing on decision making methodologies. The previous literature reviews have two major limitations. First, the reviewed articles were considered from the data base published from 2008 to 2012. Second, the application of Decision Making Techniques (DMT) has been categorized into two techniques, one is an independent approach and another is an integrated approach technique. This is a challenging area much contributes to different situations and different area of applications. The previous literature has not considered the area of application and the problem environment which affects the supplier selection and evaluation problem. Therefore, we hope that the latest and systematic survey with different approaches would be useful for presenting the most recent effort taken on this promising area.

In a global competitive business atmosphere, customer satisfaction with the products having better quality, product variety, faster response and lower cost is an exigent task. Increase in flexibility is needed to remain competitive and respond to the fast changing market. Therefore selection of supplier is a major risk in the supply chain management. Selection of suppliers is one of the most vital mechanisms of purchasing function for a company. Supplier selection is the process by which the buyer identifies, evaluates, and contracts with suppliers. The supplier selection is a multi-criteria decision making process that includes both qualitative and quantitative factors. It deploys a tremendous amount of a firm's financial resources. In return, firms expect significant benefits from contracting with suppliers offering high value. Dickson was a pioneer in the supplier selection problem and he proposed 23 different criteria for selecting suppliers like performance history, quality, delivery, warranties, price, technical capability and financial position. In this type of selection, multiple criteria cannot be considered by conventional mathematical model. Hence, we are proposing the multi-criteria decision making model. But it's not necessary that we take all 23 criteria for final decision because each firm has a different strategy in the supply chain in terms of the characteristic of the product. The MCDM provides an effective framework for vendor selection based on the evaluation of multiple divergence criteria. The decision makers always express their preferences on alternatives or on the attributes of suppliers, which can be used to help rank the suppliers and select the most desirable one. Several methods have been proposed to solve the supplier selection problem. Some of them are the linear weighting methods, the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Data Envelopment Analysis (DEA), Fuzzy Set Theory (FST), Genetic Algorithm (GA), Artificial Neural Network (ANN) and Mathematical Programming Techniques (MPT).

A supply chain is a network of facilities and distribution options which performs the roles of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to end users. The concept of supply chain management was originally introduced by consultants in 1980s and has gained tremendous attention now. Several issues were identified and addressed by the researchers such as network planning, supplier management and physical distribution. Among those, supplier management is the key issue because more than 60% of the sales revenue is spent for the purchase of raw material. Supplier management comprises the supplier evaluation, supplier selection and supplier development. Over the years, the significance of supplier selection has been long recognized and emphasized. In today's competitive operating environment it is impossible to successfully produce low cost, high quality products without satisfactory vendors. Thus one of the important purchasing decisions is the selection and maintenance of a competent group of suppliers. More recently, with emergence of the concept of supply chain management, more and more scholars and practitioners have realized that supplier selection and management to be a vehicle that could be used to increase the competitiveness of the entire supply chain.

The supply chain encompasses all activities associated with the flow and information of goods from the raw materials stage to the end user. SCM is the integration of these activities through which the improved supply chain relationships are obtained to achieve a competitive advantage. The evaluation of supplier is an unstructured decision problem because of lack of adequate needed information and the availability of qualitative information in the form of elusive sense. In supplier decisions, two fundamental questions must be addressed that what principle should be used and secondly what methods can be used to compare the suppliers.

In manufacturing, lean philosophy mainly focuses on waste reduction. Nowadays, several manufacturing companies must follow the all new technology and tools for efficiently and effectively to present themselves as a good competitor in the global economy. Lean manufacturing is the basic technique for improving the production rate with minimum available resources. Toyota Production System is the inventor of lean production techniques. Lean identifies some wastes namely excess inventory, over production, equipment breakdown, material shortages, yield loss, rework, and scrap, non-optimal performance, changeover, material transport, material storage, inspection, delays, walking and idle time. Green manufacturing is an up-and-coming philosophy of manufacturing that aims to reduce the impact on environment. By using materials that are eco-friendly and by avoiding or reducing pollution to the maximum extent, green manufacturing can be ensured and wherever possible electric power can be produced with this renewable energy sources. Sustainable practices combine Lean Green (LG) methodologies. LG practices are successfully applied in large industries. In India small scale industries are more compared to the medium and large scale industries. Now a days due to increase in cost of energy, increase in pollution, global warming, rules and regulation regarding green manufacturing and in order to sustain in this environment a company should adopt lean and green concept. Hence the possibility of application of lean green techniques in small scale industries requires to be studied and identified.

Green Manufacturing (GM) is a part of sustainable manufacturing and it can be enlightened as a type of pollution deterrence that integrates environmental deliberations in the production of goods, install the eco friendly manufacturing processes, preserve energy and natural resources, and reduce negative environmental collision. Presently all the manufacturing industries are adopting environmental sustainability for accomplishing competitive advantage. Among the sustainability orientations, measurement of environment is getting the main importance. GM and Eco-innovation has positive relationship with corporate sustainability performance, which consists of environment, economy and society. Green Supply Chain Management (GSCM) is basically management implementation in the manufacturing environment. And Sustainable Supply Chain Management (SSCM) is an improved version of GSCM. In literatures we find 22 definitions of GSCM and 12 definitions of SSCM.

The main objective of this research is to enhance the productivity in automobile manufacturing industries through developing different models like mixed integer linear programming model, balanced score card model, multi criterion decision model and hybrid data envelopment model. The method of manufacturing and selection of suppliers were also identified and discussed. Similarly, this research has focused on lean green manufacturing and green supply chain management being additional parameters for indentifying and implementing the green manufacturing system in the automotive manufacturing industries, a prime need in our country.

2.0 Prior Art

Supply chain management plays a vital role in improving the productivity and economic growth of a country, a role that would be significant in the development of human resolution for this present century, as they strive for competitive advantage: **Aaditya Desai** and **Sunil Rai (1)**. Economic liberalization and globalization are forcing the business and manufacturing organizations towards critical challenges for doing business and survival for the unproductive and ineffective organizations. For the survival in the global market productivity and effectiveness need to be enhanced significantly throughout the supply and demand chain. This may be attained by implementing some cutting edge tools and techniques in upstream side of supply during manufacturing and in downstream side during distribution: **Boas et. al. (27)**. In this process by means of existing facilities, partnerships and operating strategies are not only made more productive and effective but also have acquired new facilities, built up new partnerships and adopt new operating strategies to be more productive and effective. The management should be very careful while taking the new operating policy decisions. To concentrate on these issues more number of literatures have come up earlier and it is likely to continue in future as well. Researchers continue searching appropriate and optimal tools and techniques, which can be applied for the improvement in productivity and effectiveness throughout the supply and demand chain management. Literature review made on the above mentioned related areas relating to the application of latest tools and techniques that could be applied are given in the following section.

Huge numbers of research articles have been published already in the area of supply chain and logistics management. From this a standard review of key survey articles across various aspects of supply and demand chain with logistics management that could facilitate the reader with a preliminary tip in continuing the research has been attempted. **Xinbo Zhang et. al. (261)** developed a stochastic optimization model to formulate the problem of the global supply and demand chain management. In the developed stochastic model a deterministic equivalent formulation was derived. A proficient algorithm was developed to resolve the gradient information of the objective function and constraints due to the obscurity caused by assessing the integrals with unknown decision variables in the objective function. The algorithm results revealed that the corporations of global supply chain have to pay greater attention to the restrictions of the concerned state or central governments on the bounds of markdown rates while the market demand plays a critical role in the corporation's decision-making of global supply chain. **Xu et. al. (263)** recently presented a tri-level programming model based on conditional value-at-risk for an extended global supply chain that consists of a material supplier, a manufacturer and a retailer. **Zhang et. al. (273)** presented a multi-period, multi-commodity mixed integer programming model to optimize the global supply chain for a digital equipment corporation. However, the objective function was involved in minimization of the costs of production, inventory and transportation, the transshipment prices of the manufacturing goods were not decision variables of the model. **Hammami** and **Frein (87 and 88)** developed two optimization models for the design of global supply chains in virtue of the profit split transfer pricing method. It was claimed that the model is particularly suited in the context of off shoring, but, the inventory cost and shortage loss were not taken into consideration while developing the models.

Bai et. al. (20) recommended a seven step technique to link environmental and business performance measurements to obtain main set of necessary business and environmental performance measures for sustainable SCM. Sustainable SCM provides a competitive advantage to the organizations since it creates the opportunity to differentiate from other competitors by being fair in sufficient utilization of natural resources, careful not to destroy the environment, being socially responsible in terms of health and safety of staff, and working economically. **Birhanu et. al. (26)** and **Balakannan et. al. (21)** described that a SCM policy defines the business model for operating a supply chain to place an organization in the competitive market. Every manufacturing goods have its own supply chain strategy and the aim is to make sure that there is increase of income with decrease of cost. **Khodakarami et. al. (118)** described that among the members in a supply chain and logistics management collaboration plans a significant role to make sure that there is faultless supply of manufacturing goods and information. Lack of teamwork leads to bullwhip result, which is very much unwanted in a supply and demand chain management system, **Hudnurkar et. al. (104)**.

Agility has been defined as the ability to succeed and prosper in an environment of constant and irregular change. An agile supply chain is an integration of business partners to enable new competencies in order to respond to rapidly changing, continually fragmenting markets. The key enablers of the agile supply chain are the dynamics of structures and relationship configuration, the end-to-end visibility of information and the event-driven and event based management **Agarwal et. al. (3)**. The main key components of agile capabilities are considered to be speed, quality, flexibility and responsiveness in the poultry product industry **Vonderembsc et. al. (249)**. The main component used in the proposed system will follow process integration. Process integration means collaborative working between buyers and suppliers, joint product development, common systems and shared information. The ability of a system to adapt to change and rapidly reconfigure in response to market opportunities becomes crucial **Zsifkovits and Engelhardt-Nowitzki (281)**. The agile methodology was very much popular in the software development process. The agile process followed in the software development can be used in other industries where there is a need for iterative release and changing requirement. An agile based supply chain model was proposed by **Nallusamy et. al. (158)** to integrate and increase the clarity among the stakeholders in the supply chain and logistics management to eradicate the mediators and to meet out the market demand at right time**. Soltany and Sayadi (220), Kuralay et. al. (128)** and **Liangmo Wang et. al. (137)** presented a model for SCM where procuring iron ore and coke from various resources with manufacturing and delivery of steel goods were examined to develop the productivity of a steel making plant in Iran. A SCM model was developed by **Nallusamy et. al. (169)** to present the essential of quality in a medium scale foundry industry over various delay conditions, rejection rates and different other factors and also examined the relationship among the supply and demand chain practices.

Alexandru Valentin et. al. (7), Miguel et. al. (151) and **Nallusamy et. al. (164)** proposed a model to evaluate the environmental performance of the supply chain and logistics were analysed in a case study industry and explained the ability to yardstick the first tier suppliers and goods of an industry. It also acted as a decision support tool to describe the various measures to be taken for developing the environmental performance of the supply chain in international level. A case-based reasoning system was developed by **Yuan and Chiu (269)** to support for assigning the appropriate weights by means of the balanced scorecard design. For an efficient case recovery, a genetic algorithm was engaged for facilitating all weighting altitudes by balanced scorecard and for deciding the most suitable three level characteristic weights. The review on the field of supply chain and logistics performance management particularly in the field of automotive industry was carried out by **Nallusamy et. al. (161)** and offers a new idea related to the automotive supply chain and logistics management. **Dornhofer et. al. (65)**, **Nallusamy et. al. (160)** and **Singh et. al. (217)** presented detailed suggestions for Performance Management System (PMS) in automobile manufacturing industries and also performance indicators to monitor the supply and logistics management.

More recently, with emergence of the concept of SCM, more and more scholars and practitioners have realized that supplier selection and management to be a vehicle that can be used to increase the competitiveness of the entire supply chain **Dag Naslund and Steven Williamson (56)**.

The evaluation of supplier is an unstructured decision problem because of lack of adequate needed information and the availability of qualitative information in the form of elusive sense. In supplier decisions, two fundamental questions must be addressed, like what principle should be used and secondly what methods can be used to compare the suppliers. A hybrid model by combining with AHP was developed for selecting the best supplier for an automobile manufacturing industry. A study by the help of a survey which was conducted in 300 business organizations was carried out. The purchasing managers of those organizations were requested to identify the factors that were influencing the supplier selection. As an outcome of the survey, totally 23 factors were identified as important factors for the supplier selection decision problem. Supplier selection is complicated by the fact that various criteria must be considered in the decision making process.

The analysis of criteria for selection and measuring the performance of the suppliers has been the focus of many research papers. Around seventy four research articles on supplier selection were reviewed, which identified the following: Delivery, net price, quality, production capability, geographical location, technical capability, reputation, financial position, performance history and warranty being the most contributed criteria for supplier selection. The relative importance of supplier selection criteria on quality, service, price and delivery were also reviewed. **William Ho (254)** made review about the literatures of the multi-criteria decision making approaches for supplier evaluation and selection. This research not only provided evidence that the multi-criteria decision making approaches were better than the traditional cost-based approach, but also aided the researchers and decision makers in applying the approaches effectively. A data envelopment analysis model to evaluate alternative suppliers for a multinational corporation in the telecommunications industry was executed. Eleven evaluating factors were considered in the model, in which there were six inputs related to the supplier capability and five outputs related to the supplier performance for performance monitoring of suppliers.

Supply chain management acts as an important role during the development of a product, survival in the market, maximization of production rate and energetic contacts between the suppliers and customers. An efficient way of recapturing the value of a product and the proper disposal of material, the remanufacturing industries finds difficulty in the design of reverse logistics **Song Hua and Wang Lan (221)** and **Sonia R. et. al. (222).** During last few years, the area of reverse logistics has been given more attention by many industries and academicians. Due to environmental impact and economic performance, there should be proper management to reverse the flows of products and parts to reduce the negative impact on the environment. This necessitates a proper mix of recovery options which is a great challenge in reverse supply chain.

The option for the recovery of returned products consists of reuse, resale, repair, refurbishing, remanufacturing, cannibalization and recycling. Among recovery of product, repaired ones are collected in the collecting site and usable products are cleaned, refurbished, and transported to manufacturing site **Jianmai Shi, Guoqing Zhang and Jichang Sha (110)**. In re-manufacturing and recycling process, used products are disassembled into parts in the disassembled site and transported back to the manufacturing site. Reverse logistics is a very vast field of study with various issues being addressed such as remanufacturing, commercial returns, end-of-life returns and so **on Matar et. al. (147).** Designing a closed loop supply chain to address these issues would be an arduous task and may result in inefficient network **Kannan e.t al. (113)** and **Ozceylan et. al. (178)**. The reverse logistics could be categorized broadly in to three major areas, namely distribution planning, inventory control and production planning. A framework to manage the product returns by estimating selected categories of products in the context of a developing country was proposed **Cruz-Rivera, R. and Ertel (55)**.

Yin et. al (266) proposed an augmented DEA approach for selection of suppliers. The model was capable to handle imprecise data to rank the efficient suppliers and covered the discrimination among them based on discriminating efficient suppliers from relatively poor performers. **Wu and Blackhurst (255)** proposed a supplier evaluation and selection methodology based on an extension of DEA to evaluate suppliers. The weight constraints were introduced to reduce the possibility of having inappropriate input and output factor weights. **Rohit Kumar Mishra and Patel (201)** developed an application guideline for the assessment, improvement, and control of quality in SCM using DEA. Improvement in the quality of all supply chain processes lead to cost reductions as well as service enhancement. **Atefeh Amindoust (14)** stated that the multiple attribute utility theory based on DEA applied to tackle this problem taking into consideration certain inputs and outputs. A real case study was implemented to show the application of DEA method by which the efficient and inefficient suppliers were identified to rank them.

The money blocked in the form of inventories, raw material, work-in-process and finished goods are a measure of the responsiveness of the supply chain to market demand. The inventory expressed in terms of number of days of sales at any point of time determines the time taken to introduce a new product in market and hence indicates the number of days the firm is removed from the market **Wei, Y.C. (252)**. Transportation entails moving inventory from point to point in the supply chain. It is formed of many combinations of mode and routes, each with its own performance and characteristics **Shamsodin Nazemi (211)**. Reduced supply chain vulnerability to risks arose through horizontal collaboration amongst producers, and vertical collaboration with the processor and retailer. Producers improved market and price security, and pig performance. For the processor and retailer the collaboration generated greater security of supply of an assured quality, improved communication with suppliers, and reduced demand risk as they could assure consumers on quality, animal welfare and product provenance **Leat and Revoredo Giha (131)**.

Lean manufacturing is nothing but lean and manufacturing. Simply we can say that it is the lean value for industry and customer. **Subha and Jaisankar (226)** and **Zhu (279)** aims to evolve sector-specific lean manufacturing practices (LMP) with special reference to engineering goods manufacturing industries. They were duly validated to show how they would lead to higher volumes of production through minimum use of resources and thus achieve competitive advantage through operational benefits. **Manoj Ade (144)** suggested that the productivity improvement through lean manufacturing means optimization and co-ordination of the input resources to minimize the wastes to reduce total production cost. **Ramamoorthy (192)** put forwarded about implementing the lean manufacturing tools and techniques in the pump manufacturing premises for taking necessary steps to fulfill the customer demand and expectations. **Hudli Mohd (103)** described the development of key areas which will be used to assess the adoption and implementation of lean manufacturing practices. **Ramesh (193)** discussed about the simulation study carried out for proposing one-piece lean line layout with features of lean manufacturing. The lean initiatives that can be addressed are, introducing Kanban replenishment system, better work-in-process, changing the layout, visual management techniques, standardized work for the reduction of cycle time, number of workers and number of setups.

A green supply chain performance measurement structure was described by **Bhattacharya et. al. (24), Nallusamy et. al. (168)** and **Schmitz (207)** for an intra-organizational joint decision making approach. Green balanced scorecard was used within the collaborative decision making approach using a fuzzy analytic network process (FANP) to support in getting at a reliable, precise and timely data supply across overall cross functional areas of a business. The executed approach helps the industry to recognize additional requirements of the collaborative data across the supply chain and logistics information about consumers and current markets. In general, the above approach helped managers in deciding if the suppliers' performances meet the manufacturing industry and environment principles with efficient human resource, **Nallusamy et. al. (167), Ravi Kumar and Satya Meher (195)** and **Ravi Lidoriya et. al. (196)**.

In addition to make sure the PMS is in line along with the manufacturing industries policy that will improve policy achievement at lower level management that leads to increase in the policy attainment, **Melnyk et. al. (149)**. The recent development in automotive supply chain and logistics additional accentuate the constraint for rethinking the logistics of PMS, **Nallusamy (156)** and **Neto (173)**. A balanced scorecard strategy map was proposed to investigate the types of linkages through which supply chain and logistics management practices harmonise with financial and non-financial performance, and also achieve the industry policy goal by **Nallusamy (157)** and **Okongwu et. al. (174)**.

The final results exposed that there are several strategic roots that link the supply chain and logistics management practices and also other insubstantial possessions related to financial performance **Nallusamy et. al. (159)**. Green manufacturing is an important methodology and its applications through firms are discussed and explained by **Paula (181)**. **Kumar P (126)** studied about how to estimate the pollutants released from the foundries. The aim was to use 'Lean and

Green' production to improve industrial compliance with effluent regulations. **Virender Chahal (247)** stated that the effect of implementation of flexible manufacturing system (FMS), lean manufacturing system (LMS) and green manufacturing. An organizational theoretic review of green supply chain management literature was given by **Saman and Guoqinq (204)** and **Sarkis (205)**. **Torielli (237)** suggested that the lean manufacturing is more than a set of lean tools that can optimize manufacturing efficiencies and it is a process and mindset that needs to be integrated into daily manufacturing systems to achieve sustainability. Lean and green manufacturing have a positive impact on operational performances when implemented simultaneously. **Geoff Miller (79)** and **Leigh Smith (134)** explained the lean and green manufacturing with a case study of a small furniture manufacturing company.

Green manufacturing is a part of sustainable manufacturing and it can be enlightened as a type of pollution deterrence that integrates environmental deliberations in the production of goods, install the eco friendly manufacturing processes, preserve energy and natural resources, and reduce negative environmental collision **Remo A.P. Filleti and Diogo A.L. Silva (198)**. Presently all the manufacturing industries are adopting environmental sustainability for accomplishing competitive advantage. Among the sustainability orientations, measurement of environment is getting the main importance. GM and Eco-innovation has positive relationship with corporate sustainability performance, which consists of environment, economy and society. Green supply chain management is basically management implementation in the manufacturing environment. And sustainable supply chain management is improved version of GSCM. In literatures it is given that there are 22 definitions of GSCM and 12 definitions of SSCM **Payman Ahi and Cory Searcy (182)**. Sustainability is not forced but it depends upon the will of the organization for a change. To protect, maintain and improve present life styles and preserve them for future, companies are voluntarily coming forward to become sustainable. Thus, sustainability in the manufacturing system is the key to address various problems of production and operations in industry. Maruti Udyog Ltd took some steps forward to make its products sustainable, therefore other companies should also come forward to adopt sustainable manufacturing practices so as to secure the future of coming generations **Vinod kumar et. al. (245)**.

Management commitment, government initiatives, green sourcing, green design, green operations, green packaging, reverse logistics, environmental management system, green innovation and customer awareness are some basic drivers of GSCM system **Guo-Ciang et. al. (84)** and **Ali Diabat and Govindan (8)**. And also these definitions are somewhat related with environment, economic and society. The usages of triangular and trapezoidal membership functions to overcome ambiguity associated with numerical values were insisted. The membership functions are used for transforming the linguistic variables into fuzzy numbers **Siva Prasad et.al. (219)**.

A methodology for evaluating the environmental impact of a manufacturing process using decision making potential and flexibility of a knowledge based system was described. They developed a knowledge based model for sustainability assessment and applied the model in a paper manufacturing industry. A tool called Indicators for Sustainable Production (ISP) to measure the sustainability which includes both core and supplemental indicators to improve performance and support decision making was developed. They also explained how ISP can assist ISO 14001 program to measure environmental and financial performance and to gain long term benefits. **Pope et. al. (187)** discussed the Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) concepts which use Triple Bottom Line (TBL) approach for sustainability assessment. They also compared TBL approach and principle-based approaches for developing sustainability criteria and concluded that principles-based approaches are more appropriate for sustainability assessment. Suitable indicators to evaluate environmental performance in a continuous improvement perspective and developed an expert system that tests the relationship of environmental parameters with productivity parameters to evaluate green productivity has been developed.

Hwang et. al. (106) described the challenges in implementing design for environment for achieving sustainability in manufacturing firms. They developed data envelopment analysis model for evaluating the performance of design for environment using Decision Making Unit and empirical data to evaluate the sustainability design of automobile industries. There are 12 common barriers **Varinder Kumar Mittal and Kuldip Singh Sangwan (242)** of GM and among them diffusion of GM has highest importance due to lack of awareness/information in language of insufficient information about the existing technology choices and limited access to the information. The impact of drivers on GM can be calculated by fuzzy approach and giving them fuzzy number and according to this priority or rank should be decided **Govindan et. al. (81)** and **Varinder Kumar Mittal and Kuldip Singh Sangwan (243)**.

There are enormous numbers of studies which have taken place in literature, occupy different methods in supplier selection. Particle swarm optimization (PSO) based fuzzy neural network has been used to derive rules for qualitative data in achieving more precise supplier selection decision **Chakraborty et. al. (37)**. The application of ant colony in supplier selection process enables to solve many combinatorial optimization problems within a reasonable time **Tsai et. al. (239)**. **Raja Nazim et. al. (190)** suggested a combination technique of analytical hierarchy process together with supply chain operation reference (SCOR) model to develop new decision support system (DSS) to the industry. There are four stages in supplier selection process which employed the norm stages of supplier selection process:

data gathering, AHP calculation, SCOR evaluation, and implementation of decision making. Data analyzed was aligned with evaluation of data to synthesize priorities and consistencies measurement. Organization's decision maker would gain benefits and acquire competitive advantage providing DSS practitioners to achieve a success of the holistic approach in future decision support system.

Jianliang Peng (109) used AHP as the evaluation model of logistic outsourcing services. He also said that based on the evaluation index system including logistics cost, the logistics operation efficiency, the basic qualities of service suppliers and logistics technology level are more practicable and also more targeted. Agent based ecommerce systems that react to buyers' feedbacks; a fuzzy approach measures the degree of customers' focus, on products using fuzzy logic. **Mohanty and Passi (153)**. **Kuo et. al. (127)** used ANN and multi criteria decision making techniques to select environment friendly supplier selection. **Davood and Mellat-Parast (58)** developed grey-based decision-making model for supplier selection. **Khaleie et. al. (117)** proposed novel intuitionist fuzzy clustering approach to aggregate decision maker's preferences in supplier selection problem. This proposed model created in addition to providing satisfactory and an acceptable result, avoids time-consuming computations and consequently reduces the solution time. To name another advantage of the proposed model, we can point out that it enables us to make decision based on different levels of risk **Mohsen and Md. Sabbagh (154)**.

Fuzzy Analysis Network Process (FANP) is integrated with fuzzy multi-objective linear programming (FMOLP). An integrated model for supplier selection, FANP-FMOLP model was developed by **Lin (140)**. The model can be used to monitor organizations activities so as to avoid subjective human decisions and to improve the relationships with the suppliers. **Fattahi et. al. (74)** proposed a framework for the performance measurement of the chain in strategic and tactical levels in which the ranking of indices are also among the achievements.

A novel instuitionistic fuzzy superiority and inferiority ranking (FSIR) method to solve the uncertainty group multi-criterion decision making problem was proposed. They applied the instuitionistic fuzzy sets to define the fuzzy natural language terms which are used to describe the individual decision values and the weights for criteria and for decision makers. Many researchers proposed many methods for supplier selection with limited criteria. **Ordoobadi (177)** described a decision model that applies fuzzy arithmetic operators to manipulate and quantify decision maker's subjective assessments. **Aksoy and Ozturk (6)** presented a neural network based supplier selection and performance evaluation system in JIT production environment. **Kerim Goztepe and Semra Boran (116)** provided an idea to select a supplier when more criteria are involved using MCDM tools. By extending their work, a study was conducted for supplier selection using AHP, FUZZY LOGIC and artificial neural network. **Wu (257)** integrated, decision tree and ANN approaches and used in supplier selection. **Thiruchelvam and J.E. Tookey (236)** provide an overall picture of research on supplier selection problems and supplier selection practices.

Yossi Aviv (267) discussed about a joint, two-stage supply chain with two members of manufacturer/retailer and supplier and also studied the relations between inventory and forecasting in a two-stage supply chain of a solitary product that faces stochastic demand. **Tae Cheol Kwak et. al. (231)** discussed about the supplier-buyer models for the negotiation process over a long term replenishment contract. He has given two different models such as supplier leading model and buyer-driven model. **Sun Chaoyuan and Guo Xirui (229)** and **Terry et. al. (235)** have studied about supply chain management relationship and the impact of repeated interaction on capacity investment and procurement. **Chi-Leung Chu and**

Jorge Leon (48) have presented about the supply chain inventory coordination with private information. They considered the problems of coordinating serial and assembly systems with private information where end product demands are known a finite horizon. **Selcuk Karabat and Serpil Sayın (209)** discussed about the coordination problem in a single-supplier/multiple-buyer supply chain with vertical information sharing. They proposed a model for each buyer's net savings expectations based on their limited view of the entire supply chain which consists of self and the supplier only, and then included these expectations into the modeling of the supply chain conducted by the supplier. Practical simulations results in system dynamics modeling and simulation of a particular food supply chain, showed dynamics could contribute to improve the knowledge of the complex logistic behavior of an integrated food industry.

Huang et. al. (102) focused the specific scenario of optimizing the configuration of the supply chain system given commonality among platform products. **Graves and Willems (82)** considered on dynamic programming in supply chain modeling. **Dimitrios Vlachos et. al. (64)** made an attempt to the development of efficient capacity planning policies for remanufacturing facilities in reverse supply chains, taking into account not only economic but also environmental issues, such as the take-back obligation imposed by legislation and the 'green image' effect on customer demand. The behavior of the generic system under study is analyzed through a simulation model based on the principles of the system dynamics methodology.

Dharamvir Mangal (62) signified the ways to achieve total quality management using supply chain management principles in process industries. **Kumar Sanjay (125)** expressed that material is one of the essential resources without which not even a single industry will function and therefore, optimum utilization of this resources will contribute a lot in overall improvement in material productivity. **Daniel Rexhausena et. al. (57)** displayed about the key link between a company's internal supply chain activities and its customers. **Bigliardi et. al. (25)** provided a structured performance measurement system tailored for the food supply chain. **Mohammad Reza Soltany et. al. (152)** presented a supply chain management model in which purchasing iron ore and coke from different resources, along with production and distribution of steel products were investigated to improve the productivity of a steel making plant in Iran and which was designed based on a single objective concept with a focus on total cost minimization.

Spitter et. al. (223) developed a linear programming model for supply chain operation planning with capacity constraints for assembly. **Xiaozhen et. al. (260)** developed a conceptual operational framework for the steel company using supply chain techniques. **Farahani and Elahipanah (73)** devised a dual objective model for just-in-time distribution in the context of supply chain management for distribution network of a three-level supply chain. **Seifbarghy et. al. (208)** studied a supply chain performance assessment in a steel company based on supply chain operations reference model. An attempt for optimization of work condition and production of blast furnace was made by **Helle et. al. (92)**. A dynamic optimization model of the supply chain was developed by **Peng (183)** and **Hongyu Wang et. al. (99)**. It achieved optimal system profit under conditions guaranteeing a certain level of customer satisfaction. Applying this model to coal production of coal mine allows recommendations for a more systematic use of washing and processing, transportation and sale resources for commercial coal production.

Reuben Slone et. al. (199) stated that, if you are disengaged from supply chain management, you run the risk of sabotaging partner strategy and customer relations and leaving money on the table now and for the long term". With this detailed insight into literature review validates the need for a strong performance measurement and analysis system that shall improve the supply chain performance, which forms the basis of this research work. It is essential to integrate environmental management practices into the whole supply chain management in order to achieve a greener supply chain and maintain competitive advantage **Rao and Holt (194)** and also increase business profit and market share objectives. Various definition of GSCM exists in the literature.

Accordingly, **Zhu and Sarkis (277)** defined GSCM as has ranged from green purchasing to integrated supply chains starting from supplier, to manufacturer, to customer and reverse logistics, which is "closing the loop". According to **Srivastava (224)**, GSCM can be defined as integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life. It has become clear that the best practices call for integration of environmental management with ongoing operations. One study from Germany conducted by **Large and Thomsen (130)** identified five potential drivers of green supply chain management performance: green supply management capabilities, the strategic level of purchasing department, the level of environmental commitment, the degree of green supplier assessment, and the degree of green collaboration with suppliers.

Azevedo et. al. (18) examined the links between green practices of supply chain management and supply chain performance in the context of a particular in firm automotive supply chain. This study obtained the conceptual model from data analysis that provide evidence as to three practices that have positive effects on quality, customer satisfaction and efficiency and also negative effects on supply chain performance. In the study of **Chiou et. al. (49)** in Taiwan have explored the correlation between greening the supplier and green innovation in Taiwan industry by using structural equation modeling. They concluded that greening the supplier through green innovation leads to significant benefits to the environmental performance and competitive advantage of the firm. The study from Japan conducted by **Arimura et. al. (12)** determined the influence of ISO 14001 certification on the green supply chain management by using Japanese facility level data. The study proved that ISO 14001 and also voluntary EMS government program significantly influence GSCM practices.

These programs evaluate their suppliers' environmental performance and ask suppliers to undertake specific environmental practices. Another study from Japan by **Zhu et. al. (275)** sought to introduce environmental, green supply chain management experiences of large Japanese manufactures. This work shows that the large companies can green their supply chain by creating win-win relationships with their partners, and hence realize the sustainable growth for the entire supply chains. Moreover, it also indicated that suitable regulations and policies set by government can help GSCM circulation from larger leading companies to smaller companies. **Hsu and Hu (101)** investigated the consistency approaches by factor analysis that determines the adoption and implementation of GSCM in Taiwanese electronic industry. The fuzzy analytic hierarchy process method was applied to prioritize the relative importance of four dimensions and 20 approaches among nine firms in electronic industry. Meanwhile,

Shang et. al. (212), Shi et. al. (214) and **Shi Yongqiang et. al. (215)** explored key green supply chain management capability dimensions and firm performance based on electronics-related manufacturing firms in Taiwan. On the basis of a factor analysis, six green supply chain management dimensions were identified such as green manufacturing and packaging, environmental participation, green marketing, green suppliers, green stock, and green eco-design. **Holt and Ghobadian (97)** investigated the level and nature of greening the supply chain in the UK based manufacturing sector. In this study, the work explores the driving forces behind environmental and the specific management practices Vis a Vis the relationship between them. The study by **Nawrocka et. al. (171)** in Sweden, has concentrated on the role of ISO 14001 in environmental supply management practices in Swedish companies. The study described the existing and potential role of ISO 14001 for three key operational tasks of environmental supply chain management: to communicate the requirements to the supplier, to motivate and enable the supplier, and to verify that the supplier follows the requirements. Moreover, the study from South Korea carried out by **Lee (133)** has identified the drivers of participation in green supply chain initiatives by considering small and medium-sized suppliers and their most important stakeholders, including buyers and the government.

Raymond et. al. (197) examined the relationship between supply chains and environmental performance of SMEs in Canada. This study proved that time and financial resources to deal with solid waste and energy issues are the most limiting factors. In addition, **Chen (45)** looked into the relationship between green innovation and green image of companies in Taiwan. The study proposed a new concept of green core competence. **Chien and Shih (47)** examined the adoption of GSCM practices among the electrical and electronic industry in Taiwan. The relationship between green supply chain management practices and environmental performance, as well as financial performance has been studied.

Simpson et. al. (216) explored the moderating impact of relationship conditions existing between a customer and its suppliers and effectiveness of the customer's environmental performance requirements. Practically no research exists on the actual effectiveness of green supply requirements when placed in context with the realities of inter-organizational dynamics. Green Supply Chain Management in Developing Countries is believed to represent the environmental friendly image of products, process, systems and technologies, and how the business is conducted **Vachon and Klassen (241)**.

Sun Zhiyi and Qian Chuanfu (230), Xu Yi (262) and **Zhu et. al. (276)** investigated whether different Chinese manufacturer clusters varying in their extent of implementing GSCM exist from the ecological modernization perspective. The study also examined whether Chinese manufacturers' awareness of local and international environmental enhancing energy savings and pollution reduction oriented compliance is related to GSCM implementation and also whether a mediating effect of regulatory pressure plays a major role. The study found the varying pace of Chinese manufacturers to ecological modernization with GSCM practices and the significance of regulatory pressure to distribute the practices for adoption by Chinese manufacturing industry. The study confirmed that a company's environmental management capacities will be strongly enhanced by frequent internal training of employees to increase its involvement in GSCM practices. Another research from China, studied by **Li (136)**, examined the adoption levels of GSCM practices in China and explored the performance measurement for GSCM. The findings demonstrated that GSCM was strongly balancing to other advanced management practices, and contributed to improving environmental performance.

Zhu et. al. (278) evaluated GSCM practices relating to closing the supply chain loop for four Chinese industries (power generating, chemical/petroleum, electrical/electronic and automobile). They concluded that adoption of GSCM practices in different industrial contexts is not uniform across the four industries. Another study also by **Zhu et. al. (274)** in China has evaluated and explained GSCM drivers, practices and performance among diverse Chinese manufacturing firms. Concern about the environmental issue has also risen the interest of researchers to investigate the adoption and implementation of GSCM practices in other Asian Countries such as Thailand, India and Malaysia. A study in Thailand analyzed the recent green activities in computer parts' manufacturing industries and also measured the level of green supply chain management. The in-depth interview regarding green procurement, green manufacturing, green distribution, and reverse logistic was conducted. One study from Malaysia that has been carried out by **Eltayeb and Zailani (69)** has identified the four key drivers or motivators to green supply chain initiatives: Regulations, customer requirements, expected business gains, and social responsibility.

Diabat and Govindan (63) and **Eltayeb et. al. (68)** analyzed the relationship between green supply chain initiatives and performance outcomes and identified the key initiatives (eco-design) that have positive effect on the four types of outcomes (environmental, economic, cost reductions, and intangible outcomes). In recent years, the competitiveness among global supply chain has grown resulting in new challenges in the area of process system engineering (PSE) which include an enhanced management of the chemical supply chain. Among the SCM developments that have been proposed to reduce the supply chain cost and to increase profitability are the effective distribution of resources over the supply chain network, collaboration and coordination between supply chains considering all participants enterprises.

Hjaila et. al. (94), integrated marketing and financial issues, Sustainability, and incorporation of demand management and corporate financial decisions. These issues can be addressed at different hierarchical decision levels, through designing the supply chain, providing an improved master plan, and/or controlling the involved operations, **Amaro and Barbosa-Povoa (10), Cao et. al. (34), Zeballos et. al. (272), Zamarripa et. al. (271)** and **Hjaila et. al. (96)**. The coexistence and coordination of different individual objectives have been analyzed using approaches based on Game Theory, such as in the work of **Hjaila et. al. (95)**, who has represented the individual objectives as non-cooperative non-zero-sum stackel-berg game considering the risk associated with the uncertain nature of the third parties. **Yue and You (270)** developed an integrated strategic and tactical bi-level model for the optimization of non-cooperative multi-echelon supply chain considering the objectives of both customers and manufacturers under the leading role of the manufacturer; however, their approach considers that the manufacturer echelon dominates the decision-making process, disregarding the individual objectives of the suppliers' echelon supply chain.

In small and medium enterprises (SME) logistic and SCM have both positive and negative effects. On one hand, SCM can supply quality, cost, client service, leverage and even risk reduction repayment for the SMEs and on other hand it exposes the SMEs to greater management and control hazards whilst reducing its private differentiation benefits **Hong and Jeong (98)**. The process of achievement of transport services is involved in the traditional trade-off between quality and cost, which leads to obtain a better process as a whole. On the other hand, the management of transport focuses on monitoring obtained and desired service levels, which transcends the boundaries of the company.

This involves management relationship with the operator's needs and proficient logistic services that can move their freights at the right place, at the right time, in the right circumstance, and at the right rate**.** As a result, the success of small company has a direct effect on the national economy. At present, SMEs are increasingly taking part in the worldwide business network and contributes in many interlinked supply chains **Hvolby and Trienekens (105)**. SMEs have significant effects on supply chain that show the roles of suppliers, distributors, producers, and clients. SMEs usually focus their activities on precise position markets by their exclusive competences in the supply chain. SMEs can take advantage of the supply chain management strategy for different reasons such as SMEs are critical links in several supply chains, SMEs are very flexible and many SMEs still young and developing and it is consequently easier for them to reengineer existing business processes and adopt a supply chain management than for large organizations with a long-standing organizational structure and customs.

Technology is increasingly reasonable and available to help SMEs to take benefit of supply chain strategies because of the competitive pressures being faced by small businesses. It is critical for them to use supply chain viewpoints and connected strategies to create synergies with supply chain partners in order to succeed in the global competitive environment. SMEs are now increasingly taking part in the global business network and participating in many interlinked supply chains **Marra et. al. (145)**. The present background is of great business opportunities, dynamic, and globalized economy; companies need to find procedures and management methods that increase the development of efficient organization with enhancing results. This paradigm has been the subject of several studies, which has focused their attention to the purpose and to the different affects as well as the meaning of each of the companies' competitive achievement **Stock et. al. (225)** and **Vasiliu et. al. (244)**.

The logistics sector development is unbalanced, but consistent with the evolution of the Romanian economic environment, characterized by concentration in few centers of Bucharest, Arad etc **Felea (75)**. Results of applying genetic algorithm (GA) to a wide variety of supply chain network design (SCND) problems have been very promising among other evolutionary algorithms **Yeh (265), Fahimnia et. al. (71)** and **Altiparmak et. al. (9).** Even though, the strengths of GA as a combinatorial optimization algorithm, this algorithm has a limited efficiency in intensifying the local search process. **Hasani et. al. (90)** proposed an efficient memetic algorithm based on the GA which incorporates adaptive variable neighborhood search (VNS) as a local search heuristic for solving large-scale GSCND problems. Various mathematical models for different business environments and disruption occurrences were developed to employ the aforementioned resilience strategies. **Aryanezhad et. al. (13)** proposed a stochastic integer non-linear programming (INLP) model for the supply chain network design which uses extra inventory to decrease the impact of disruptions.

Jabbarzadeh et. al. (108) proposed a comprehensive robust network design model for the blood supply during and after disasters in a real case study. Managing global supply chains has become crucial in recent years due to the increase in globalization and international competition **Cagliano et. al. (32)**. Complexity in designing global supply chain (GSC) networks has increased. Due to this expansion of GSC across borders lead-time is necessary among supply chain facilities in order to cover greater distances. In addition to creating a need for lead-time, globalization also increases the possibility of exposure to natural disasters, creating more complexity in designing GSC networks, as international business environments must manage these disruptions and uncertainties **Aydin et. al. (15)**.

Hishamuddin et. al. (93) proposed a real time recovery mechanism to determine a recovery schedule for disrupted production facilities using a two-stage supply chain network design model. **Schmitt et. al. (206)** compared the impact of supply disruptions and demand uncertainty on the performance of a centralized two-echelon inventory system to that of a decentralized one. They found the decentralized inventory system fared better in cost variance reduction through the risk diversification effect than the centralized system. **Azad et. al. (17)** presented a method for designing a reliable stochastic supply chain network in the presence of random disruptions which may occur in both distribution centers and transportation modes.

Melo et. al. (150) and **Peng et al. (184)** proposed a mixed-integer linear programming (MILP) supply chain network designed model in which disruption occurrences were modeled using the robust optimization approach and p-robustness criterion. They consider protective resources that take into account the partial damage of capacitated facilities involving areas rather than single facilities. **Costantino et. al. (54)** presented a MILP model for designing an agile supply chain by considering the multi-source supply in managing disruptions. **Benyoucef et. al. (22)** presented a mathematical model for designing a supply chain network with consideration of reliable and unreliable suppliers.

Fang. et al. (72) proposed a model in order to examine the performance of a wide variety of sourcing strategies for a manufacturer under supplier disruptions. **Wu et. al. (259)** proposed a discrete time model for the assembly structure of supply chain network problems under disruptions and addressed its wide variety of applications.

Baghalian et. al. (19) proposed a stochastic mathematical formulation for designing a multilevel supply chain network under disruption and uncertainty in both supply and demand sides for multiple products. **Ganesh and Periyasamy (77)** proposed a real-time recovery mechanism to determine a recovery schedule for disrupted production facilities using a two-stage supply chain network design model.

Bueno-Solano and Cedillo-Campos (31) analyzed the impact of occurrence and propagation of disruptions on the performance of GSCs and found roughly a 600% increase in the inventory level of GSCs under disruptions versus the same GSC's under normal operating conditions. This increase in inventory is mainly due to the security issues on countries' border areas that lead to a longer lead-time to meet the demand. In addition, **Liberatore et al. (139)** and **Tang (233)** highlighted the importance of analyzing the propagation impact of disruptive events on the SC's performance. They point out disruptions should not be considered as isolated instances, particularly when disruptions are a result of disastrous events, i.e., natural disasters. In designing flexible and resilient GSC networks, one must consider an isolated disruption may cause a series of correlated or cascading disruptions **Madadi et. al. (143)** and **Cantor et. al. (33).** Although

Flexible and resilience strategies are required when dealing with disruptions, many strategies like production of semi-manufactured products and keeping inventory are considered redundancies within some management paradigms, such as lean and agile production **Christopher and Lee (52)**. Two contributions were presented like a proposed model for GSC networks under disruptions and uncertainties and a proposed solution algorithm. In this, several aspects of global supply chain network design (GSCND) studies, international considerations in GSCND, disruption and uncertainty considerations in GSCND as well as solution algorithms for GSCND models were reviewed, **Hammami et. al. (89)** and **Choi et. al. (50)**.

Global supply chain networks faced uncontainable occurrences and disruptions **Elkins et. al. (67)** and **Corominas (53)**. Supply chain facilities are exposed to disruptions due to various failures, such as man-made failures, natural disasters, transportation delay, and power outages **Gedik et. al. (78), Pengn et. al. (185)** and **Khosrojerdi et. al. (119)**. A conceptual model for managing disruptions was proposed by **Kleindorfer and Saad (121)** in which risks in supply chains were considered. In order to design a responsive and resilient supply chain network under disruptions, effective resilience strategies are required, such as multiple sourcing, extra inventories and demand postponement.

Park et. al. (180) presented the best practices and lessons learned from several catastrophic natural disasters which affected global supply chains in Japan. Another consequence of the expansion of supply chains across borders is uncertainty from internal and external sources such as the change of demographics and political conditions, the availability of raw materials, and the fluctuation of energy prices **Goh et. al. (80), Zsidisin (280), Wu and Zhan (258)** and **Ivanov**

and Sokolov (107). Accessibility to low-cost resources, large markets, and potential incentives for international investments are economic and competitive advantages that encourage considerable attention toward designing and managing GSC model developments **Meixell and Gargeya(148)**.

In designing GSC networks, various international considerations, such as international logistic issues, exchange rates, tax rates **Perron et. al. (186)**, import/export tariffs, as well as state foreign trade and investment regulations should be taken into account. In addition, locating global facilities, selecting location of manufacturing or distribution facilities, selecting technologies and assigning transportation costs between different partners should be considered in designing GSCN models.

When designing GSCN models, particularly where supply chain performance is concerned, regional and international trade agreements are also important. Tax rates, transfer price regulations and import tariffs are examples of factors in global supply chains that are affected by regulations set by economic unions **Hammami and Frein (86)**.

The transfer prices play a key role in the global supply chain networks and are highly correlated with the location decisions. Most companies are motivated by the possibility of manipulating transfer prices in order to shift profits from countries where income taxes are relatively high towards low tax countries to maximize their global after tax profit. Applications of stochastic programming techniques for large-scale GSCND models are limited because of the shortage of historical data for fitting probability distributions for uncertain parameters **Hasani et. al. (91)**.

A robust optimization approach could be adopted to handle uncertain parameters. This approach provides a feasible solution under all possible realization of uncertain parameters within their bounds with the best objective function value between all the robust feasible solutions.

Robinson and Bookbinder (200) developed a mixed-integer programming model to design a GSC considering north American free trade agreement (NAFTA) in order to minimize the total cost of GSCs. Utilization of opportunities offered by NAFTA are considered in the proposed model **Wilhelm et. al. (253)**. **Singh et. al. (218)** presented a model of the multi-stage GSCND problem incorporating various scenario-based risk factors, including the late shipment, exchange rates, quality problems, logistics and transportation breakdown, and production risks. Minimizations of total shipping cost of reverse logistics in a multi stage network were addressed by priority based genetic algorithm and through a heuristic approach. The onward logistics multiechelon distribution inventory supply chain model and closed loop multi-echelon distribution inventory supply chain has been integrated **Nallusamy (163)**.

An important question of reverse logistics namely remanufacturing in which a model that jointly determines the quantities of remanufactured product, the production quantities of new branded product and the acquisition prices of used product was addressed **Ozceylan et. al. (179)** and **Nallusamy (165)**. But, product recovery options were not explored before and a mixed integer nonlinear programming model for automotive component re-manufacturing company to maximize the profit of multi echelon reverse logistic network addressed the gap in this area **Wang and Hsu (250)**.

To bring the external suppliers in to the CLSC network an integrated model with a supplier selection with evaluation of quality criteria was framed by fuzzy method **Safie Sidek et. al. (203)** and **Nallusamy (170)**. Integration with four variants of reverse logistics network with dedicated warehouse delivery locations were focused and found that for different scenarios, a single product and single period will perform well with constant demand and uncertain returns **Subramanian et. al. (227)**. The issues related to inventory management in CLSC and developed deterministic and stochastic model for a two echelon system and also several models are available for the integration of forward and reverse logistics network **Subrata Mitra (228)** and **Nallusamy (160)**.

Reengineering has become more popular in many manufacturing sectors especially in automotive industries where the lean manufacturing may be implemented to reduce the lead time and hence the productivity has been increased **Terkar et. al. (234)** and **Nallusamy (166)**. The existing available supply chain models and methods and identified topics for future research consideration that will facilitate the advancement of knowledge and practice in the area of supply chain design and analysis have been reviewed. Based on the above literature a very detailed description was made with different parameters for the enhancement of efficiency through supply and demand chain management in automotive manufacturing industries.

3.0 Aim and Objectives

Supply chain management being a critical concern of any business occupies a pivotal role every stage of manufacturing and business process that ensures an effective flow of goods and services in order to meet the customer demand. Demand chain management where focusing on the different processes that involves in meeting the customer demand sees that the best of relationships is maintained between suppliers and customers. Supply and demand chain management is a complex sensitive issue with high noise and should be dealt with carefully using appropriate tools and techniques. The main objective of this research is to develop a rational approach to improve productivity and effectiveness of the supply and demand chain in automotive manufacturing industries. The following cutting edge tools and leading edge methodologies used in this thesis are exotic, eclectic and esoteric and meant for improvement in productivity and effectiveness of the industries.

- To develop a mixed- integer linear programming model to configure the closed loop supply chain (CLSC) network while could be optimized for maximizing the profit by determining the fixed order quantity inventory policy in various sites at multiple periods. The proposed model to configure the CLSC network has been solved by using IBM ILOG CPLEX OPL studio and the results of the model shall be analysed with numerical investigations followed by sensitivity analysis.
- To create a balance scorecard model for the evaluation of reliability and performance of automotive manufacturing industries in relation to their supply and demand chain management system. The model shall be

designed based on the characteristics of design and development, manufacturing point, financial requirement and consumer's point of view.

- To examine the two issues such as area in which the application being focused more and which decision atmosphere gets attention more by review of existing 51 articles related to the area of supplier selection.
- To evaluate the performance of existing vendors using AHP, being a powerful and flexible decision making tool for complex multi criteria problems.
- To find out the best available material handling system for a warehouse using an algorithm. This proposed algorithm is a hybrid of AHP performance model and capital investment. This concept is rational, logical, exotic and comprehensive; simple calculations are performed to judge and compare the performance of the alternatives.
- To select the best possible suppliers for a manufacturing firm using ANP model a multi criteria decision making tool, which allows for the consideration of interdependencies among and between levels of attributes, considers both qualitative and quantitative factors.
- To propose an integrated decision model of hybrid Data Envelopment Analysis (DEA) for selection and evaluation of supplier. When there are several inputs and outputs in the supplier selection problem this model helps in evaluating suppliers' performance.
- To evaluate the performance of distribution centers using an algorithm. Being a hybrid algorithm write both DEA and AHP helps to develop an overall performance measure of the organization.

- To identify the possibility of application of lean green techniques in small scale manufacturing industries.
- To develop a comprehensive model for assessment of environmental sustainability using multi-grade fuzzy approach and to test the practical effectiveness of the developed model.
- To exhibit the improvement in productivity and effectiveness of the organization utilizing the above tools through the attainment of SCM and DCM knowledge.

4.0 Case Studies

In this section, different case studies were carried out in real life situation and are discussed individually.

4.1 Mixed-Integer Linear Programming Model of Closed Loop Supply Chain Network for Manufacturing System

4.1.1 Problem Definition:

In the manufacturing point of view, there are various types of CLSC network that could be presented. Among all these types of network, we have proposed here a generalized form of CLSC structure with initial inventory at manufacturing plant, distribution site, retailer site and final end period inventory with various demand of product. In this study, the structure of reverse logistics consists of a manufacturer, collection site, repair site, disassembly site, disposal site and recycling sites. After using the products, some of the customers returned the used products in different periods at collection site and they are segregated in to two types of returned products. One as commercial product returns which are sent to the repair site for refurbishing and to carry out the minor repairs. Second are the products that could be taken to the disassembly sites and disassembled into smaller parts. The unused parts can be disposed at the disposal site and the usable parts in the form of end-of-life can be sent to recycling site for processing and the accepted quality parts in the form of end-of-use taken to part inventory during multiple periods.

4.1.2 Methodology:

In this research a study was made to maximize the profit of the manufacturer with various costs associated with it. The methodology starts with a detailed study about CLSC networks in manufacturing industries and with further analysis located the problem. Data were collected for developing the proposed CLSC network and to identify the various activities. The mathematical modelling was developed with different parameters and its variables. Then the developed model was optimized and validated using IBM ILOG CPLEX optimization studio, an analytical decision support kit. Finally, the observed results of the model were analysed with numerical investigations followed by sensitivity analysis. The various stages of research are given in Figure 4.1 as methodology flow chart.

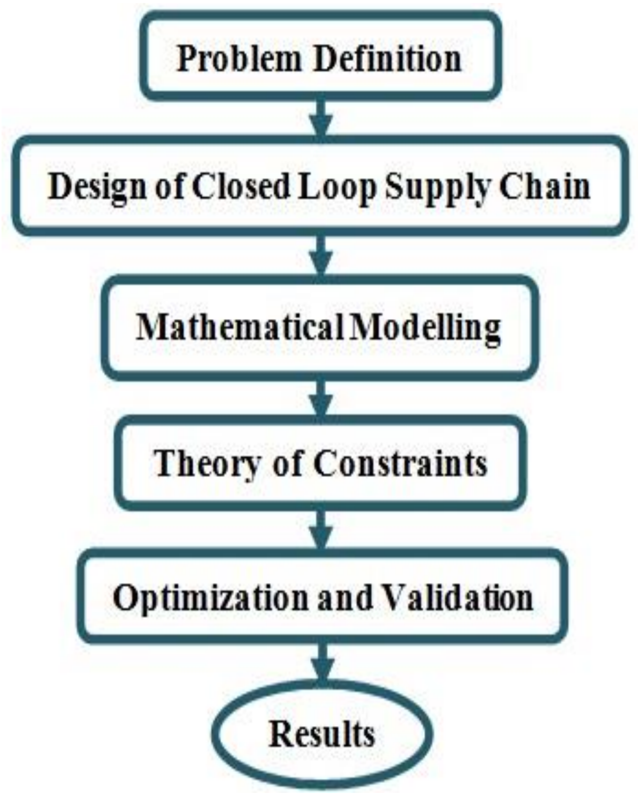

Figure 4.1: Methodology Flow Chart

4.1.3 Proposed Model:

The aim of this work is to develop a model to determine the quantity of products and parts at various sites for multiple periods by using fixed order inventory policy to maximize the profit of the CLSC. In this study, the structure of reverse logistics consist of a manufacturer, collection site, repair site, disassembly site, disposal site and recycling sites as shown in Figure 4.2. In this model three types of product recovery are considered such as commercial returns, end of life returns and end of use returns along with important aspect of inventory positioning. Further, if the demands of the product during multi period are more than the returned products then manufacturer has to produce new products. This model is designed based on the demand of product during multiple periods and determines the inventory of product and part mix at different sites. For the purpose of calculating the overall manufacturing cost, the setup cost, inventory cost and shipping cost and also maximum capacity of repair site, disassembly site, recycling site and manufacturing site were considered.

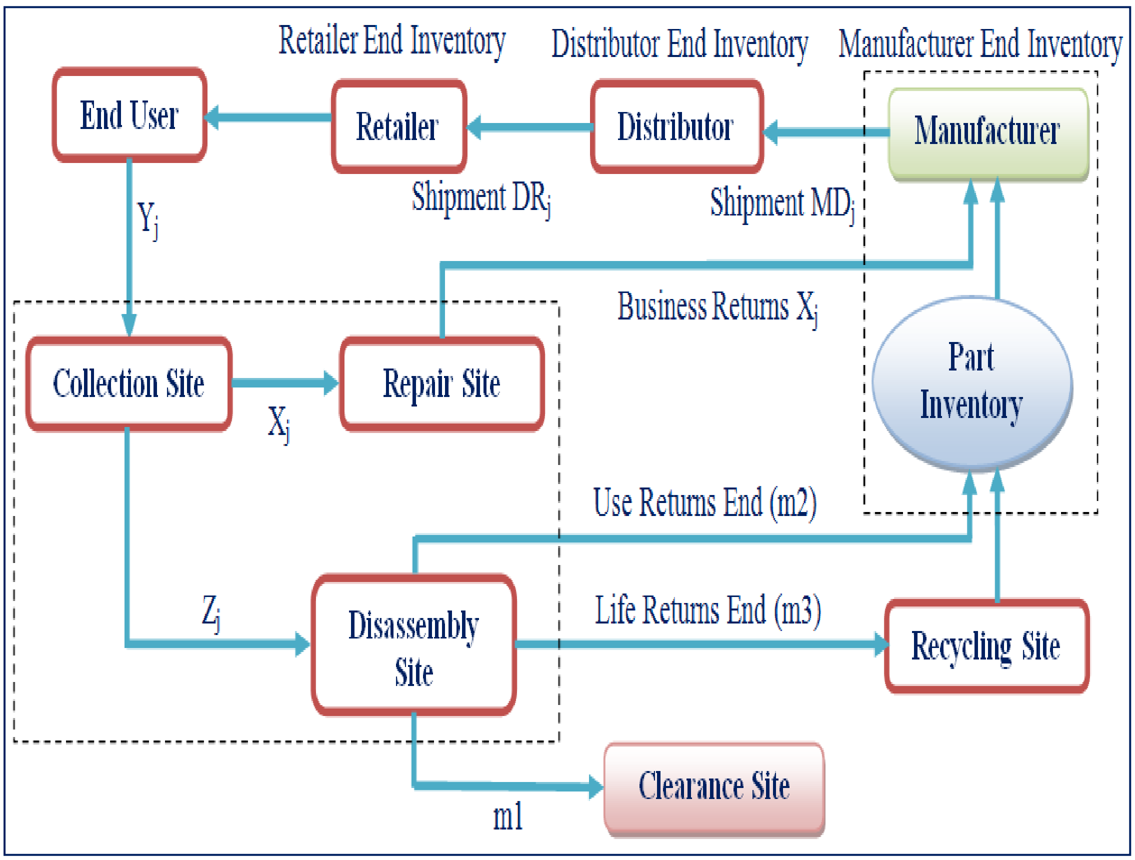

Figure 4.2: Proposed Model of CLSC

4.1.3.1 Model Formulation and Assumptions:

The indices, parameters and its associated decision variables and the mathematical model formation of the proposed closed loop supply chain are given under the heading of objective functions and cost parameters. For computation purpose, the various input data and assumptions were considered.

The Assumptions Involved in Development of CLSC Network Model:

1. The proposed model is a multi-period model.
2. The demand of product is known for all the periods.
3. The model consists of one product and three major parts A, B and C in which part A is of two quantities.
4. The capacity of the collection site is unlimited.
5. The loop follows continuous review policy.
6. The initial inventory of the manufacturer, distributor and retailer is known.
7. Lead time for each site is taken as one.
8. Collecting, disassembly and repair sites are sited under one roof and their shipment lead time is zero.
9. Reorder level and ordering quantity are known at retailer, distributor and manufacturing site.
10. Part inventory is located inside manufacturing site.
11. If the quantity of parts from recycling site is not enough to meet the requirement of the manufacturer then manufacturer should procure from external supplier.
12. Shipment cost for product and part at each site is known.

Objective Functions and Cost Parameters:

Max Z: Revenue = Cost incurred at various sites (Retailer + Distributor + manufacturer + Collecting + Disassembly + Repair + Disposal +Recycling)

Revenue:

$$\sum_{t=1}^{T} S_j(D\_R_{jt}) \quad \text{-- (1)}$$

Retailer Cost:

$$Ir(CR) + \sum_{t=1}^{T} CR(Start\_Inv\_R_{jt}) + \sum_{t=1}^{T} Or(A_{jt}) + \sum_{t=1}^{T} BCr(BL\_R_{jt}) \quad \text{-- (2)}$$

Distributor Cost:

$$Id(CD) + \sum_{t=1}^{T} CD(Start\_Inv\_D_{jt}) + \sum_{t=1}^{T} Od(B_{jt}) + \sum_{t=1}^{T} BCd(BL\_D_{jt}) + \sum_{t=1}^{T} CShip\_DR(A_{jt}) \quad \text{-- (3)}$$

Manufacturer Cost:

$$Im(CMP) + \sum_{t=1}^{T}(CMP)(Start_{Inv_{M_{jt}}}) + \sum_{t=1}^{T} CM\,Pr\big(Inv_{DisA_{it}} + Inv_{DisB_{it}} + Inv_{DisC_{it}}\big) + Im(cj) + \left(\frac{\sum_{t=1}^{T} Inv_{MA_{it}} + \sum_{t=1}^{T} Inv_{MB_{it}} + \sum_{t=1}^{T} Inv_{MC_{it}}}{a1+a2+a3}\right)(cj) + \sum_{t=1}^{T} PurA(ShipSP_{it}) + \sum_{t=1}^{T} PurB(ShipSP_{it}) + \sum_{t=1}^{T} PurC(ShipSP_{it}) + \sum_{t=1}^{T} BCm\,(BL_{M_{jt}}) + \sum_{t=1}^{T} Om\,(C_{jt}) + \sum_{t=1}^{T} Cship\_MD\,(B_{jt}) \quad \text{-- (4)}$$

Collecting Cost:

$$\sum_{t=1}^{T} CsColl(Y_{jt}) \quad \text{-- (5)}$$

Disassembly Cost:

$$\sum_{t=1}^{T} \text{CDisP}(\text{Inv\_Dis}_{jt}) + \sum_{t=1}^{T} \text{CDis Pr}(\text{Inv\_Dis}_{it}) + \sum_{t=1}^{T} \text{CsDis}(\frac{\text{Inv\_DisA}_{it}+\text{Inv\_DisB}_{it}+\text{Inv\_DisC}_{it}}{(\text{a1}+\text{a2}+\text{a3})}) + \sum_{t=1}^{T} \text{Cship\_DisDP}(\text{I}_{it}) + \sum_{t=1}^{T} \text{Cship\_DisREC}(\text{E}_{it}) + \sum_{t=1}^{T} \text{Cship\_DisPI}(\text{E}_{it}) \quad \text{-- (6)}$$

Repair Cost:

$$\sum_{t=1}^{T} \text{Crep}(\text{Inv}_{\text{Re}}\ \text{P}_{\ jt}) + \sum_{t=1}^{T} \text{d}_{j}(\text{X}_{jt}) + \sum_{t=1}^{T} \text{CShip}_{\text{Re}}\text{P}(\text{D}_{jt}) \quad \text{-- (7)}$$

Disposal Cost:

$$\sum_{t=1}^{T} \text{CsDSP}(\text{Ship}_{it}) \quad \text{-- (8)}$$

Recycling Cost:

$$\sum_{t=1}^{T} \text{Crec}(\text{Inv}_{\text{Rec}_{it}}) + \sum_{t=1}^{T} \text{CsRcl}(\text{shipDSRCA}_{it}) + \text{ShipDSRCB}_{it} + \text{ShipDSRCC}_{it}) + \sum_{t=1}^{T} \text{Cship\_RecPI}(\text{G}_{it}) \quad \text{-- (9)}$$

The above mentioned objective functions can maximize the total profit of the company. The equation (1) denotes the total revenue earned by selling the products. The cost function in equation (2) refers to the various cost incurred in retailer site. The first part represents the initial inventory holding cost. The second part represents the inventory holding cost for each time period. The third part represents the ordering cost and fourth part denotes the backorder cost. The cost function in equation (3) linked to the various cost incurred at distributor site. The first part represents the initial inventory holding cost. The second part represents the inventory holding cost for each time period. The third part represents ordering cost and fourth part denotes the backorder cost. The fifth part represents the shipment cost of products sent to retailer. The cost function in equation (4) is connected to the cost at the manufacturing site. The first part represents the initial inventory holding cost. The second part represents the inventory holding cost for each time period. The third part represents the holding cost for parts. The fourth part denotes the initial manufacturing cost. The fifth part represents the manufacturing cost of products using the parts from part inventories. The sixth, seventh and eighth parts represents the purchase cost of parts A, B, C from the supplier. The ninth part represents the backorder cost. The 10th part represents the ordering cost for the manufacturer. The eleventh part denotes the shipment cost for products sent to the distributor. The cost function in equation (5) denotes the collecting cost.

The cost function in equation (6) gives the disassembly cost. The first part represents the holding cost of products at disassembly site. The second part represents the holding cost of parts at disassembly site. The third part represents the disassembly cost for products at disassembly site. The 4th, 5th, 6th part represents the shipment cost for the parts sent to disposal site, recycling site and to the part inventory. The cost function in equation (7) denotes the various costs at repair site. The first part represents the holding cost of products at repair site. The second part represents the repair cost for product at repair site. The third part represents the shipment cost of products sent to manufacturer. The cost function in equation (8) denotes the disposal cost of parts. The cost function in equation (9) denotes the various costs at recycling site. The first part represents the holding cost of products at recycling site. The second part represents the recycling cost for parts at recycling site. The third part represents the shipment costs of parts A, B, C sent to part inventory at manufacturer. For validation and computational work, certain constraints were formulated and different input parameters were taken in to account. For the optimization of the numerical model, some of the parameters were formulated and are shown in the following Table 4.1.

Table 4.1: Numerical Model with Parameters and their Indices

Indices	Parameters	Value
Ir	Initial inventory at retailer	8000
Id	Initial inventory at distributor	8000
Im	Initial inventory at manufacturer	8000
Sj	Unit selling price of the product	8000
Cj	Unit direct manufacturing cost of a product	30
Dj	Unit repair cost of a product	1
Or	Ordering cost for retailer	4000
Od	Ordering cost for distributor	4000
Om	Ordering cost for manufacturer	4000
Cship_DR	Total shipment cost for products from distributor to retailer	8000
Cship_MD	Total shipment cost for products from manufacturer to distributor	8000
Cship_DisREC	Total shipment cost for parts from disassembly to recycle site	5000
Cship_DisPI	Total shipment cost for parts from disassembly to part inventory	5000
Cship_RecPI	Total shipment cost for parts from recycle to part inventory	5000
Cship_DisDP	Total shipment cost for parts from disassembly to disposal site	10000
Cship_REP	Total shipment cost for products from repair site to manufacturer	5000
DIS	Maximum capacity of the disassembly site	800
CsColl	Unit collecting Cost	1
CsDiss	Unit disassembly cost	3

CsDSP	Unit disposal cost	2
CsRcl	Unit recycling cost	2
a1	Unit requirements of Part A to produce one unit of product j	2
a2	Unit requirements of Part B to produce one unit of product j	1
a3	Unit requirements of Part C to produce one unit of product j	1
Pur A	Unit purchase cost of part A from supplier	15
Pur B	Unit purchase cost of part B from supplier	20
Pur C	Unit purchase cost of part C from supplier	20
m1	Maximum percentage of parts sent to disposal site	0.6
m2	Maximum percentage of end of use returns	0.2
m3	Maximum percentage of end of life returns	0.2
m4	Maximum percentage of commercial returns	0.6
m5	Maximum percentage of products sent to repair site	0.1
m6	Maximum percentage of products sent to disassembly site	0.9
CR	Unit inventory cost at retailer	0.3
CD	Unit inventory cost at distributor	0.3
CMP	Unit inventory cost for product at manufacturer	0.3
CMPr	Unit inventory cost for part at manufacturer	0.1
CDisP	Unit inventory cost at disassembly site for product	0.3
CDisPr	Unit inventory cost at disassembly site for part	0.1

Crep	Unit inventory cost at repair site	0.1
Crec	Unit inventory cost at recycling site	0.1
BCr	Back order cost at retailer	0.5
BCd	Back order cost at distributor	0.5
BCm	Back order cost at manufacturer	0.5
FOQR	fixed order quantity for retailer	4000
FOQD	fixed order quantity for distributor	4000
Sj	Maximum capacity of repair site	1000
MaxDis	Shipment capacity of truck disassembly to disposal site	1000
ShipDIS_RC_PI	Shipment trigger point for parts from disassembly site to recycle and part inventory	8000

4.1.4 Results and Discussion:

4.1.4.1 Numerical Investigation:

In this section, a numerical model has been presented. In this case the model has one product and each product is made using three different parts. Two units of part A, one unit of part B, one unit of part C are required to manufacture the product. In this research work IBM ILOG CPLEX Optimization studio v.12.5 was used to get the optimal solution. The IBM ILOG CPLEX Optimization studio is designed for modelling linear, nonlinear and mixed-integer optimization problems and the systems are useful for large and complex problems. The cost related parameters are formulated and are given in the following Table 4.2 and Table 4.3 as cost at different levels and inventory levels at different locations respectively.

Table 4.2: Cost at Different Levels

Phase	Amount Collected	Amount Disposed	Maintenance Cost	Reprocess Cost	Dealer Inv. Cost	Vendor Inv. Cost	Manufacturer Inv. Cost
1	0	0	0	0	2400	2400	2400
2	1223.6	0	120.56	0	1785	2400	2412
3	1406.1	0	138.80	0	1081	2400	2412
4	1522	0	150.2	0	1519	1200	2412
5	1497.2	0	147.92	0	1969.1	0	2412
6	1715.1	0	169.70	0	1710.5	1200	1212
7	1778.1	20000	176.01	0	2020.4	1200	24
8	1643.6	0	162.56	8000	2397.5	612	0
9	1510.4	0	149.24	0	2547.2	600	0
10	1501.4	0	148.34	0	1795.4	1200	2500
11	2132.6	0	211.46	0	728.1	2400	4900
12	1279	20000	126	0	1287.5	2400	9600
13	1704.2	0	168.62	0	1634.3	2400	14200
14	1717	0	169.7	8000	1975	1200	20100
15	1314.2	0	129.62	0	2516.6	0	25900
16	1941.2	0	192.32	0	1545	1200	31300
17	1863.2	20000	184.52	0	612.2	2400	36400
18	1758.2	0	174.02	0	1200	2400	42000
19	961.4	0	94.34	0	1916.1	2400	47500
20	838.4	0	82.04	8000	2695.7	1200	54300

Table 4.3: Inventory Level at Different Locations

Time Phase	Inventory at Retailer End	Distributor End Inventory	Inventory at Product End	Inventory at Producer Parts End	Disassembly Inventory Level	Recycling Site Inventory	Repair Site Inventory
1	8000	8000	8000	0	0	0	0
2	5955	8000	8080	0	1270	0	41
3	3608	8000	8080	0	2550	0	181
4	5068	4000	8080	0	3830	0	333
5	6569	0	8080	0	5110	0	483
6	5707	4000	4080	0	6400	0	655
7	6740	4000	80	0	7670	0	833
8	7997	2040	0	0	8950	0	1000
9	8496	2000	0	14000	2230	4000	1149
10	5990	4000	8500	16000	3510	0	300
11	2432	8000	16500	26000	4800	0	513
12	4297	8000	32000	26000	6070	0	641
13	5453	8000	47500	26000	7350	0	811
14	6588	4000	67000	26000	8630	0	983
15	8394	0	86500	32000	1910	4000	1115
16	5155	4000	104500	28000	3200	0	310
17	2046	8000	121500	30000	4470	0	496
18	4000	8000	140000	30000	5750	0	672
19	6392	8000	158500	30000	7030	0	768
20	8991	4000	181000	30000	8346	0	852

4.1.4.2 Sensitivity Analysis:

In order to validate the proposed model, sensitivity analysis was performed. In this analysis, we had fixed the various percentages of commercial returns (z) and studied the impact on profit for various set of time periods (t) versus maximum profit. From Figure 4.3 it was found that, the profit remains over a line for time period t<15. There is a sudden fall in profit t>15 irrespective of the percentage of commercial returns due to the high cost at reverse loop.

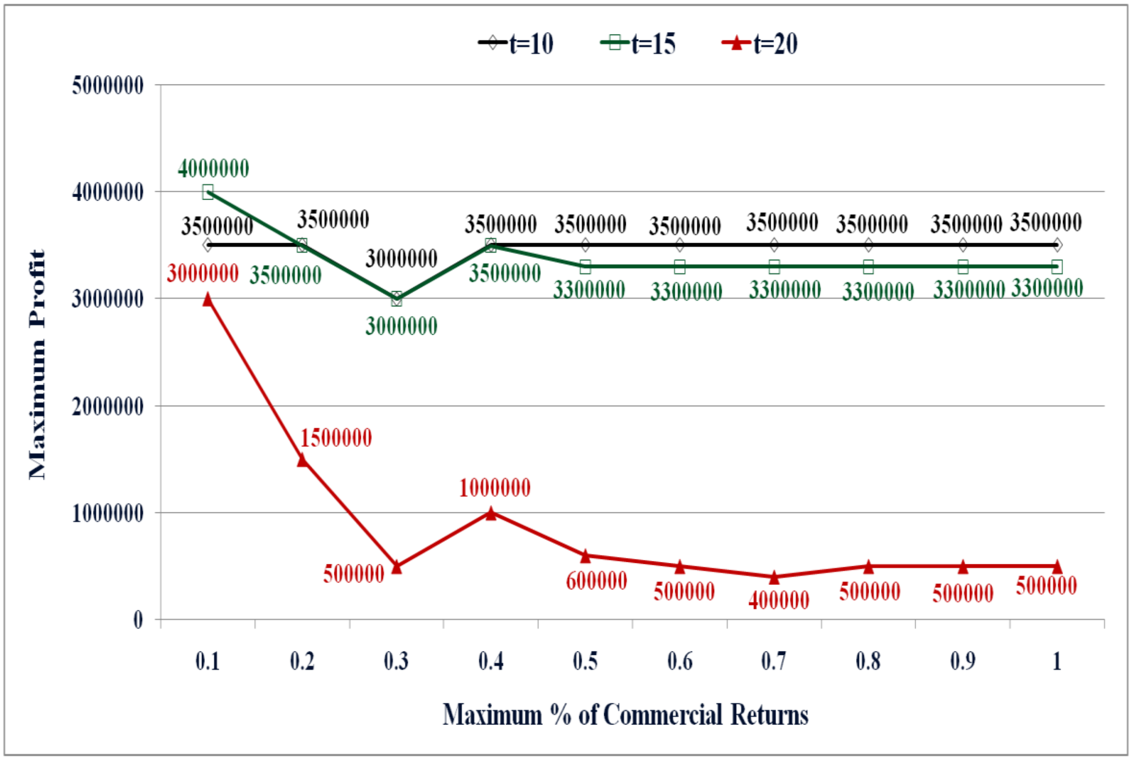

Figure 4.3: Sensitivity Analysis of Total Returns (Maximum Profit Vs Percentage)

During this analysis, we had fixed the various percentages of products sent to repair site (Xj) and studied the impact on profit for various set of time periods (t) versus maximum profit and is shown in Figure 4.4. From Figure 4.4, it was observed that there is not much difference in maximum profit for Xj > 60 % irrespective of the various time periods. Also, we have fixed the various percentages of commercial returns (z) and studied the impact on profit for maximum capacity of disassembly site versus maximum profit which is shown in Figure 4.5. From Figure 4.5, it was found that there is a decrement in profit at the point where the maximum capacity of disassembly site is 600 and following linear increment in profit in the event of increasing the maximum capacity of the disassembly site.

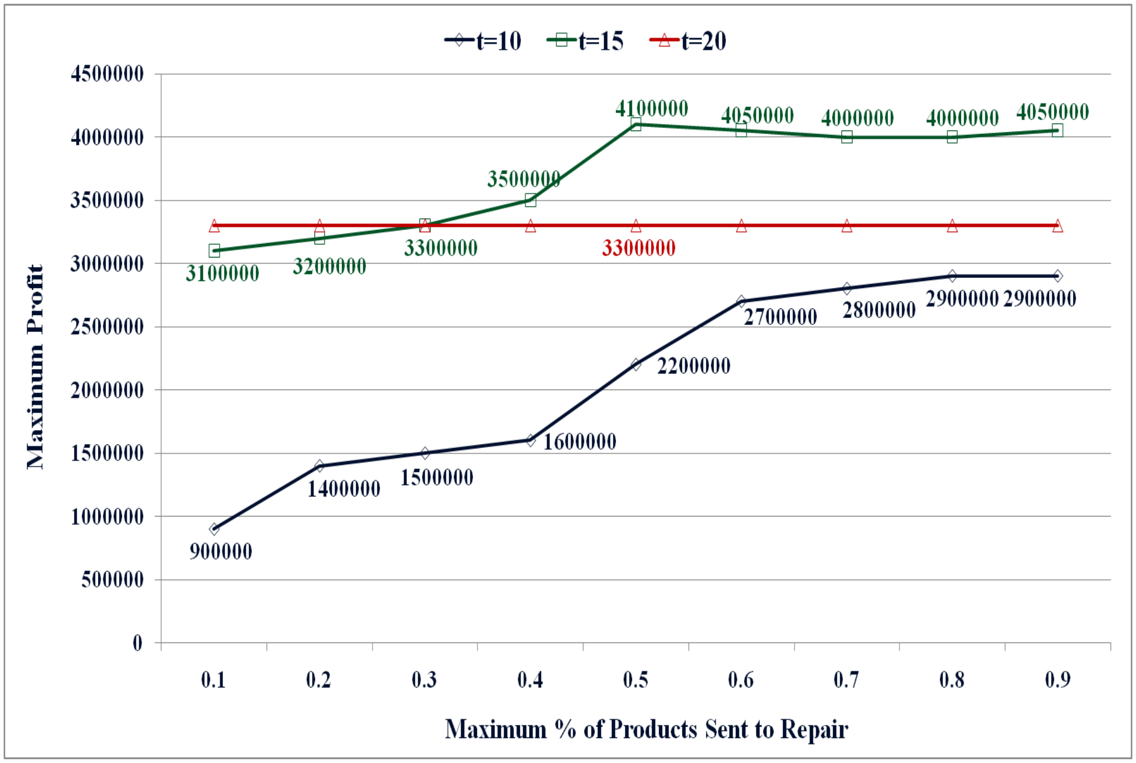

Figure 4.4: Sensitivity Analysis of Repair Sites

(Maximum Profit Vs Percentage)

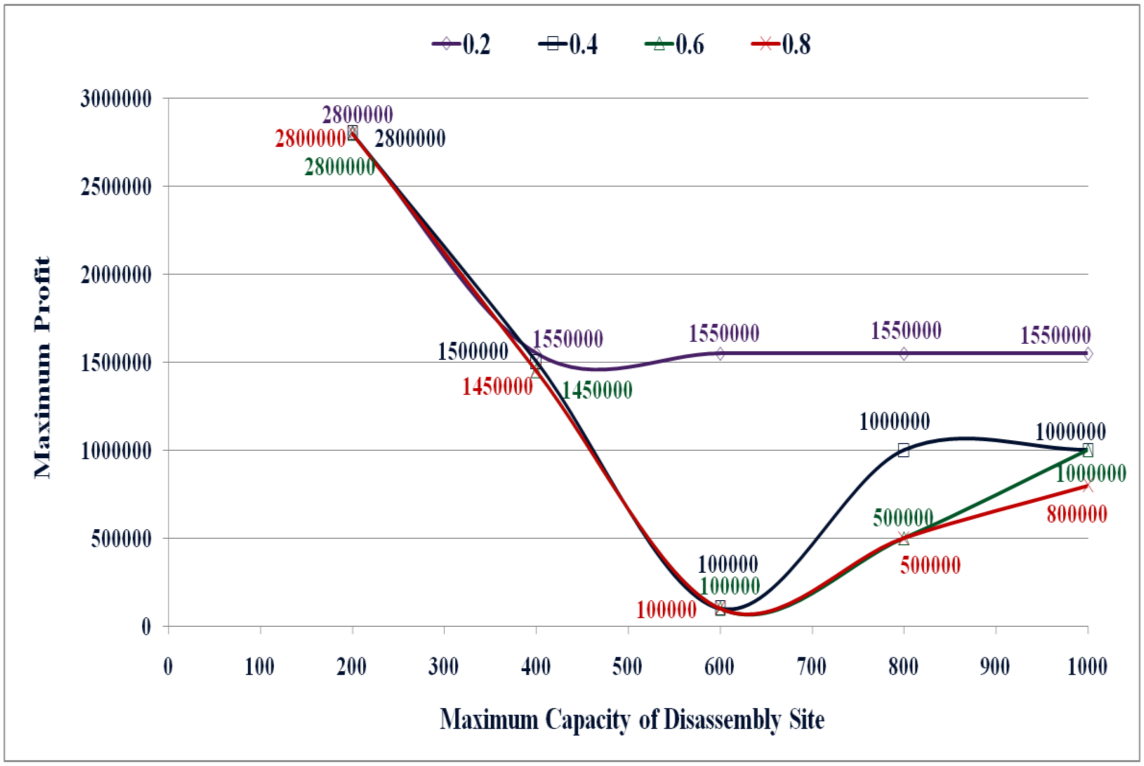

Figure 4.5: Sensitivity Analysis of Disassembly Sites (Maximum Profit Vs Percentage)

4.1.5 Conclusions:

The mixed-integer linear integrated model was developed with a manufacturer, distributor, retailer, repair site, collection site, disassembly and a recycling site. Based on the analysis and results the following conclusions were arrived.

- The developed mixed-integer linear programming model was solved by using IBM ILOG CPLEX optimization studio.
- To analyze the performance of the developed linear integrated model, numerical examples were used.
- Through the sensitivity analysis it was observed that, maximum profit of the CLSC can be attained up to 60% of the products sent to repair site.

- It was also found that, there were no significant changes beyond 60% of the products.
- From the observed results it was noted that, as the time period increases, the profit tend to decrease due to increased reverse loop costs.
- The maximum profit can be achieved, if the capacity of disassembly site is kept higher than 600 units.

4.2 Performance Evaluation of Supply Chain and Logistics Management System using Balanced Score Card for Efficiency Enhancement in Indian Automotive Industries

4.2.1 Problem Definition and Methodology:

Balanced score card is a management tool along with information offers a new idea to estimate the performance of manufacturing industries broadly by the following four aspects broadly, which have prominence and mutual collision with design and development, manufacturing point, financial requirement and consumer's point of view. The main objective is to balance among a series of signs such as balance among short period and long period goals, financial and non financial signs, delayed and leading signs, internal and external performance. Attention of management must be transferred to understand planned targets from short period goals and transfer to carry out real time analysis of causes from feedback reflection on results. The structure of balanced scorecard design principles are shown in Figure 4.6.

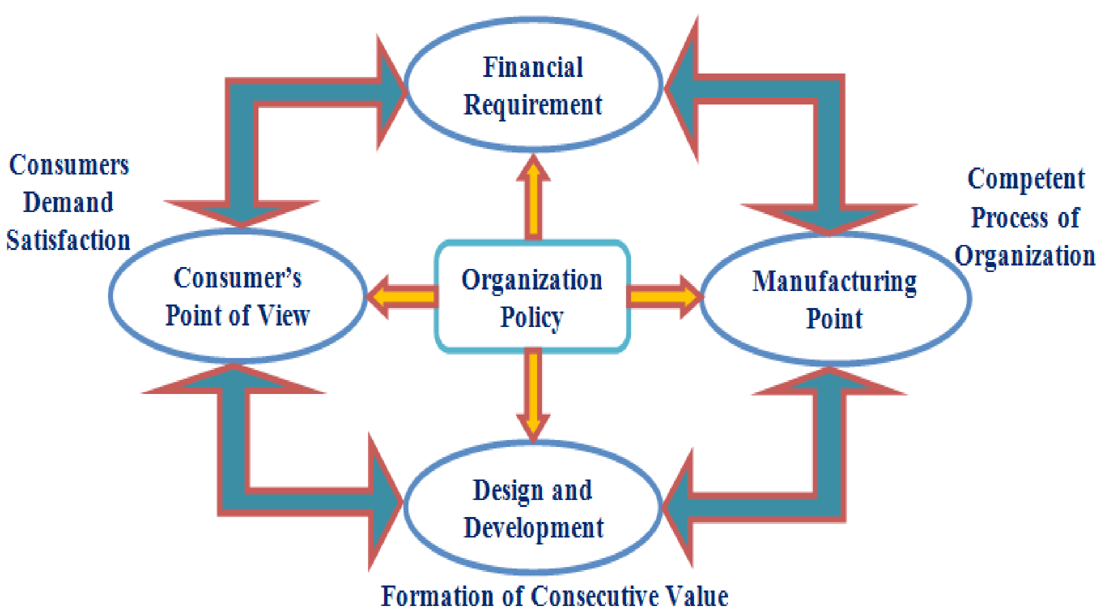

Figure 4.6: Principle Design of Balanced Score Card

4.2.2 Data Collection and Analysis:

As per the characteristics of SCM and the benefit of balanced score card, researchers and managers who took part in the Japanese logistics system society designed a new assessment score card after ten rounds of deliberations for performance of logistics and supply chain. After that, Tokyo institute of technology organized a professional seminar where many research scholars from various countries discussed and enhanced the score card. The improved score card involved four aspects like policies and firm coordination, design and execution, effectiveness of shipment and information technology. Policies and firm coordination was measured with five to seven input signs and the score card contains twenty five input parameters. In addition with score card data, the final questionnaire also covers basic information about industries. The guidelines of performance score card for logistics and supply chain management are as follows.

Policies and Firm Coordination:

The parameters considered for this guidelines are significant degree of logistics and supply chain management in industry policies, description of supplier contract items and degree of information sharing, characterization of customer contract items and degree of information sharing, essential degree on customer satisfaction and worker training and appraisal system.

Design and Execution:

Optimizing logistics policy system resources based on data flow infrastructure, market orientation comprehension and accuracy of demand prediction, precision and SCM planning adjustment, exactness and visibility of inventory control and tracking and also consistency and visibility of working procedure are the different parameters for design and execution.

Effectiveness of Shipment:

For this constraint total logistics costs, inventory turnover rate and cycle period, environmental protection awareness, Just-in-time, consumers in advance and reprinted efficiency, delivery effects and quality and visibility of supply chain inventory and identifying the ability of opportunity costs are the major roles.

Information Technology:

Usage of bar code/automatic cognition and data capture, electronic data interchange and computer in operation and decisions are the major criteria in the case of information technology.

For all kinds of business environment it is mandatory that, current management ideas give more concentration to the consumer orientation and satisfaction. Additionally financial data is an important role to estimate externality of business system. Efficiency of supply chain and logistics measure supply chain performance from external customers and output. Outstanding financial performance and customer satisfaction are entrenched in the business process of industries. To some extent, the degree of business process quality determines financial performance in industries and customer satisfaction. Design and execution aptitude reflects the internal business process of organizations and are the determinative conditions for industries to obtain high efficiency in supply chain and logistics. In advanced information technology, suitable applications greatly improve the sharing degree of information in industries and member firms of supply chains, promote the efficiency of logistics and capital flow, develop the coordinating ability of the entire supply chain and resource integration and improve the supply chain performance levels. The applied ability of information technology reflects the applied level in the supply chain management process. Policies and firm coordination provides the most important internal enterprise environment for management activities of logistics and supply chain. The coordination skill in policies and firm coordination reflects the degree of enterprise emphasis and the support foundation on employee training, logistics and supply chain management.

The score card applies Likert scale of bipolar scaling method in the industries with a 5 point scale to evaluate an index. The high scores indicate that the industries have the better performance on the index. Through common discussions of experts and relative staff in enterprise circles, the performance level represented by index scores are defined and explained. Based on the important degree of supply chain and logistics management in enterprise policies the following observations were made.

1. Top management has no definite strategy or policy about logistics and supply chain management. There is no specialized department for taking charge of logistics and SCM reformation.
2. There is a responsible department for logistics reformation, but the activity area is limited to only internal departments. High level leadership people here not participated in making logistics policy.
3. Under the instruction of high level leadership, there is a specialized organization for taking charge of logistics and supply chain management, but its influences don't permeate in to the whole company.
4. Under the support of definite enterprise policies and the charge of high level leaders, reformation of logistics management is promoted constantly.
5. There is a clear enterprise policy covering logistics and supply chain management under the leadership of the general manager, there is a system covering the entire enterprise to enhance the logistics adaptation to environmental changes.

In the year 2016, a survey team was formed with members from various education and manufacturing areas and were assigned to survey the industrial organizations within India. The survey was mainly integrated with two types, one according to relevant data collected from business directories and organizations and other from a study through a questionnaire which was e-mailed and an informal discussion was conducted with industries to fill up the questionnaire face to face. A total of 300 questionnaires were sent and 270 questionnaires were collected back of which 210 questionnaires were selected and 70% of recovery. The proportion of effective samples was 65%. After auditing these organizations from the questionnaire, they were selected as sample organizations.

Table 4.4: Feedback Result of Sample Industries

Locations	No. of Feedbacks	% of Feedbacks
Ambatur	35	16.70
Maraimalainagar	29	13.81
Sriperumputhur	35	16.70
Thirumazhisai	32	15.24
Ennur	19	09.05
Semparampakkam	13	06.19
Guindy	12	05.75
Thuraipakkam	5	02.40
Tamparam	2	00.95
Siruseri	2	00.95
Villivakkam	3	01.43
Padi	2	00.95
Ranipet	2	00.95
Vellore	9	04.29
Coimbatore	10	04.76

The feedback results from the sample organizations with the percentage of feedback are given in Table 4.4. Similarly the characterization of sample organizations with the percentage of sample size and appropriate parameters has been summarized and are given in Table 4.5.

Table 4.5: Characterization of Sample Organizations

Parameter	Characteristics of Organization	Sample Size	% of Sample Size
Industry Owned	Multinational Companies	9	16.67
	Public Limited Companies	10	18.52
	Private Limited Companies	15	27.78
	Small Scale Industries	20	37.03
No. of Employees	1-50	25	11.36
	51-100	30	13.63
	101-250	20	09.10
	251-500	20	09.10
	501-1000	50	22.71
	Above 1000	75	34.10
Total Sales	0-10	25	16.34
	11-25	55	35.95
	26-50	22	14.38
	51-100	11	07.18
	101-250	8	05.23
	251-500	7	04.58
	Above 500	25	16.34

4.2.3 Results and Discussion:

Reliability and Strength:

Reliability and strength are two main signs of questionnaire quality. Reliability refers to the reliability standard between measuring data and conclusions on whether measuring tools can measure the item degree stably in terms of stability and consistency or not. Strength means that the results measured by the questionnaire reaches the expected targets. By higher strength more measured results will displays real features of the measured objects. Based on the different emphasis, strength generally can be divided into three types such as content, relevance and structure strength. Content and relevance strength can be tested by relevant experts during the design stage of questionnaires, while the structure strength of the questionnaire can be generally tested.

Cronbach α coefficient test is the most common reliability test. In general if α coefficient is above 0.90 the reliability of the questionnaire is excellent. If it is above 0.80 the reliability is acceptable and if it is above 0.70 the questionnaire should be modified greatly. But if the reliability value is below 0.70 the questionnaire should be redesigned. Based on survey data, PSPP software was used to conduct reliability analysis with regards to the four evaluative perspectives: policies and firm coordination, design and execution, effectiveness of shipment and information technology for supply chain performance score card. The result revealed the reliability analysis of policies and firm coordination, design and execution, effectiveness of shipment and information technology as 0.80, 0.82, 0.83 and 0.82 respectively and that as the α coefficient was above 0.80 in all parameters, the design of score card for analyzing the supply chain performance to be reliable.

Structure strength demonstrates the isomorphism degree between actual results and expected evaluation, which represents that the structure of actual evaluation model can be regarded as the replacement of expected evaluation content on the structure to a great extent. For evaluating the structure strength, confirmatory factor analysis was selected. Based on the data collected through survey, confirmatory industry analysis of structure for supply chain and logistics performance score card was carried out using Lisrel software and the results are shown in Figure 4.7. It was found that the Root Mean Square Error of Approximation (RMSEA) was smaller than 0.05 and the values of Normed Fit Index (NFI), Non-Normed Fit Index (NNFI) and Comparative Fit Index (CFI) were above 0.90 representing that the model fitting was positive and the mentioned structure model could be accepted.

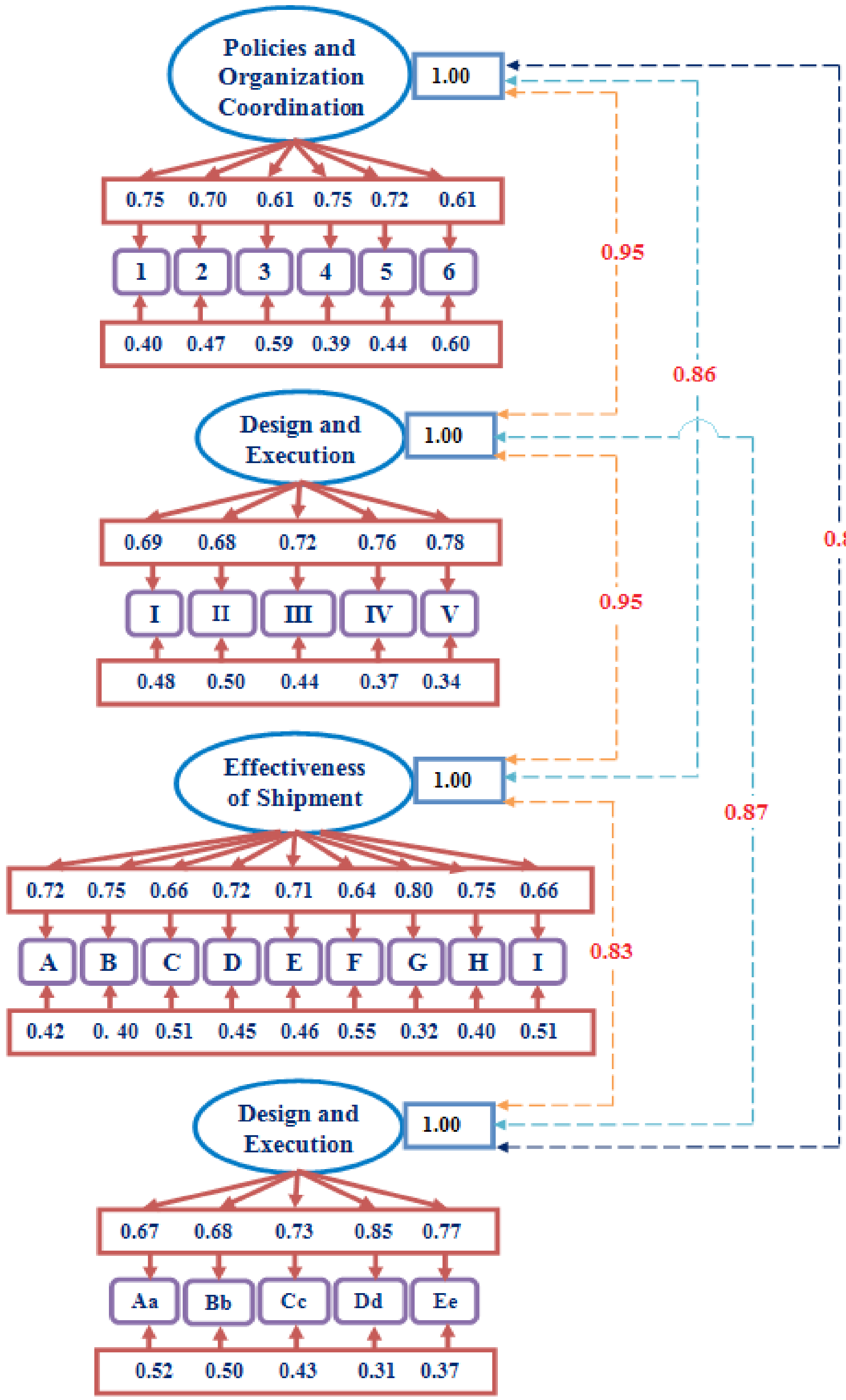

Figure 4.7: Result of Confirmatory Factor Analysis after Standardization

Comparison of Supply Chain and Logistics Performance:

The Indian economy is still in the changing phase from government planned economy to market economy. The improvement and open up policy in India launches important multinational capital. Multinational companies have already become an important part in Indian economy and account for 45% of Indian exports and 55% of Indian imports. With the economic reform in India, private industries have also developed rapidly. In 2004, employees of private industries totaled 11.7million people and this increased to 18.1 million people in 2010, so it is necessary to study the differences existing among public limited, multinational and private industries in supply chain and logistics management. The average performance of every kind of enterprise in policies and firm coordination, design and execution, effectiveness of shipment and applications of information technology is shown in Figure 4.8. It can be observed that in terms of average performance, multinational companies are superior to public limited, private limited and small scale companies in all the four aspects on the score card. It was also found that public limited companies are superior to private limited companies and small scale industries in policies, design and execution and applications of information technology but superiority of public limited companies in logistics efficiency was not clear. In non strict significance, the contributions of public limited companies in policies and firm coordination, design and execution, effectiveness of shipment and applications of information technology are inferior to contributions of private limited companies and small scale industries with regard to logistics efficiency.

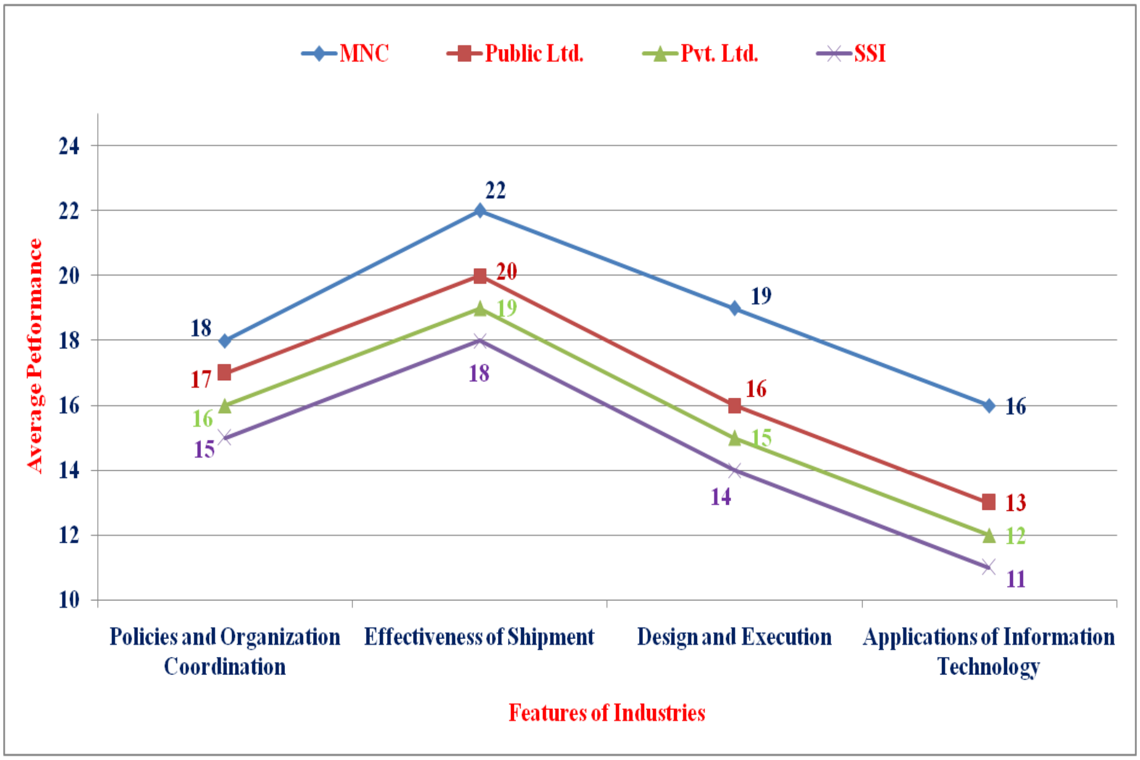

Figure 4.8: The Comparison of Supply Chain and Logistics Performance

Existing Structural Model:

Supply chain and logistics efficiency measures the performance of logistics and supply chain in firms from the characteristics of external outputs by the above mentioned design of score card and these outputs are rooted in enterprise business process. In score record, design and execution as well as applications of information technology in industries are the main signs to measure the performance of supply chain and logistics. These business processes involved in logistics and supply chains management exist in an industry or to be carried out in an industry, but are not impacted by company policies and culture. Also confirmatory factor analysis shows that there is a strong correlation between design and execution and applications of information technology. To sum up, the structural model between policies and firm coordination, design and execution, effectiveness of shipment and applications of information technology can be established and as shown in Figure

4.9. The model has been developed by giving the input in Lisrel software. The collected data are verified to acquire analysis results. The standard solutions before and after the index of structural equation model are given in Table 4.6.

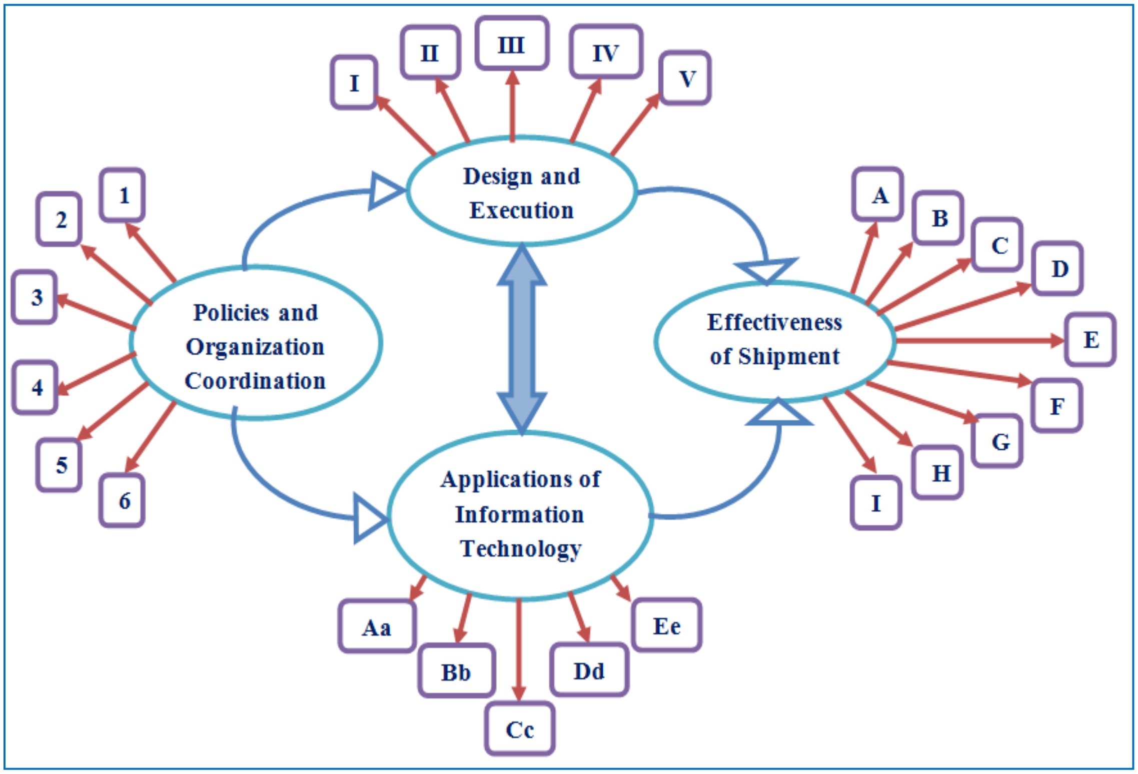

Figure 4.9: Existing Structural Model under Four Characteristics

Table 4.6: Results of Fitting Index before and after Structural Equation Model

Fitting Index	Fitting Results (before)	Fitting Results (after)
$X^2(203)$	291.54	300.27
RMSEA	0.045	0.047
NFI	0.932	0.92
NNFI	0.954	0.92
CFI	0.954	0.92

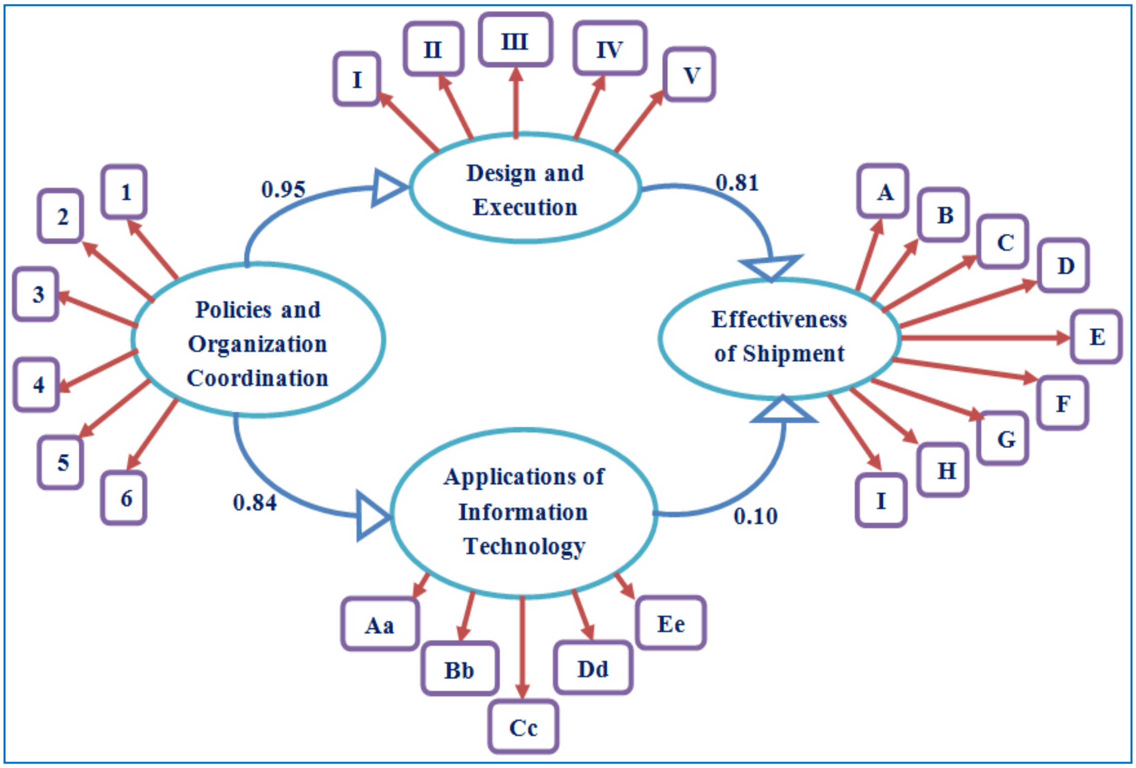

Figure 4.10: Proposed Structural Equation Model for Analysis under Four Characteristics

The model proposed in this article meets the index requirements hence this model is acceptable. The results show that there is no direct relation between design and execution and applications of information technology, so the acting connection between these parameters is removed. The confirmatory factor analysis among the design and execution and applications of information technology shows a stronger relation, because they closely depend on the same factor of policies and firm coordination. The proposed model obtained by structural equation for supply chain and logistics analysis is shown in Figure 4.10. The applications of information technology have a significant influence on effectiveness of shipment. However, influences of design and execution on effectiveness of shipment are stronger, while design and execution and applications of information technology are closely related to policies and firm coordination. Though effectiveness of shipment is one of the important indexes for customers and shareholders, excellent logistics performance cannot be separated from high quality design and execution, development and utilization of advanced applications of information technology. All of these should be the concern of a management in supply chain and logistics management. Moreover, it is also necessary to establish a long term cooperative relationship between consumers and suppliers and provide effective training for workers.

4.2.4 Conclusions:

The proposed structural equation model was developed based on the design idea of balanced score card to evaluate the supply chain and logistics performance. The model was designed from the characteristics of design and development, manufacturing point, financial requirement and consumer's point of view. From the above analysis and observed results the following conclusions were made.

1. The performance level of supply chain and logistics were evaluated using policies and firm coordination, design and execution, effectiveness of shipment and applications of information technology. Based on the analysis, a supply chain performance evaluation score card with 25 measuring indexes was developed.
2. A large scale industry survey was conducted using the designed score card within India and obtained 210 effective questionnaires. The reliability and strength of this score card was analysed using the score card. From the results it was found that the value of α coefficient was above 0.80 indicating that the design of score card for analyzing the supply chain performance was reliable.
3. From the comparative analysis it was found that the performance of supply chain and logistics among the industries, multinational companies exceeded public limited companies and private limited companies in four aspects of the score card, while public limited companies were found superior to the private limited companies and small scale industries.

4. Besides, a structural model was developed for the above four aspects and the supply chain and logistics performance was evaluated and the results were obtained. From the results it was concluded that it is essential to establish a long term cooperative relationship among customers and suppliers and provide effective training for workers.

4.3 Supplier Selection Problem in Regular Area of Application-A Review

4.3.1 Problem Definition and Methodology

The back bone of any Original Equipment Manufacturer (OEM) is the suppliers who are the major stakeholder of their supply chain. They have a main contribution in OEM's quality of the product, delivery schedule, customer satisfaction, profitability and market competiveness. Thus suitable choice of the supplier becomes an important decision making area in any business process. Proper selection of suppliers can considerably decrease production lead time, reduce manufacturing cost, increase customer satisfaction, and strengthen corporate competitiveness.

In my research, I have collected about 52 research articles published in different high rated journals during last ten years and based on these an attempt was made to examine the following two issues (i) area in which the application is being focused more? (ii) Which decision gets attention more? Finally based on the observation and analysis the necessary conclusions were made.

4.3.2 Area of Application

Manufacturing:

Out of fifty-two articles ten (19%) covers manufacturing, as the area of application while highlighting the supplier selection problem and evaluation. **Chan Felix T.S (40)** considered the manufacturing company in assembling process with risk factor through global supplier selection with four criteria describing the linguistic level of comparison between supplier and expert. By this survey **Liu Fuh-HwaFranklin (142)** considered ten suppliers out of which one was selected, then by applying eight criteria and thirteen sub-criteria, selected sixty respondents from the company four among designation of managers and supervisors after prioritizing the order of criteria or sub-criteria. **Chena Chen-Tung (46)** highlighted the fuzziness situation to calculate the distances to fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) simultaneously to calculate the ranking order of all suppliers with five criteria. **Ha Sung Ho (85)** outlines hybrid method which evaluates the Combined Supplier Score (CSS) to enable the customer to do single sourcing and multiple sourcing; a Supplier Map (SM) has been drawn for positioning of supplier performance efficiency. **Levary Reuven R (135)** presented a realistic case study on a Midwest manufacturer importing a key component essential to its assembly operation from a foreign supplier located in Wuhan, China for evaluating the best supplier in which supplier reliability was considered as a criteria. Also various researchers have presented the articles as explained above with integrated method [**Vinodh. S. et. al. (246), Rajesha, G. et. al. (191), Guo Xuesong et. al. (83)** and **Ware Nilesh, R. et. al. (251)**].

Automobile Industry:

Out of fifty-two articles ten (19%) covers automobile as the area of application in which **Bevilacqua, M. et. al. (23)** selected medium to large industries for manufacturing of clutch coupling to test the efficacy of the supplier problem and to rank the potential supplier by Fuzzy Suitability Index (FSI). Similarly many scholars have adopted automobile industry as area of application while using integrated model to solve the supplier related problem [**Celebi Dilay et. al. (35), Boran Fatih Emre, et. al. (28), Kokangul Ali et. al. (122), Yousefi Ali et. al. (268), Aksoy Ali et. al. (5), Dursun Mehtap (66), Kannan Devika et. al. (112), Kumar Amit et. al. (124) and Yazdani Morteza (264)**].

Airplane Industry:

Two papers out of fifty-two journals cover (4%) Airplane Industry as area of application in which **Aghai Shima (4)** presented a supplier selection model by adopting the factors like quantitative, qualitative, risk and volume discount using real life problem related to airplane industry. **Liou James J.H (141)** selected the data from Taiwanese company and demonstrated by assuming with gap weighted analysis that criterion is of independent nature.

Steel Industry:

Punniyamoorthy, M. (188) adopted the survey based result from among 150 respondents to integrate the structural equation modelling (SEM) and considered the uncertainties and supplier selection score. **Kar Arpan Kumar (114)** suggested that the group decision making could be handled with geometric mean and discriminate analysis could be handled by fuzzy.

Refrigerator Plant:

Two out of fifty-two journals cover (4%) the refrigerator plant for above topic. **Ustun Ozdan (240)** raised the two question regarding supplier selection, which supplier is best and how much should be purchased from the best possible supplier which considers both factors tangible and intangible with fourteen criteria. **Demirtas Egzi Aktar (60)** considered inventory lot sizing, multiple suppliers with single product and adopted fourteen criteria classified by BOCR (benefit, opportunity, cost and risk) to identify the best possible supplier.

Railway Industry:

Bruno Giuseppe (30) showed the duality between theoretical approaches and empirical applications and discussed the implication with potential barrier for firms to adopt such model.

Raw Material:

Ayuso Alonso (16) presented supplier selection by pure 0-1 programming with Branch and Fix Coordination (BFC) algorithmic approach under uncertainty.

Washing Machine Company:

Kilincci Ozcan (120) defined main attribute and sub-attribute for supplier selection and hierarchy structure by calculating weight of criteria and alternating with fuzzy to achieve best possible supplier.

Textile Industry:

Three articles out of fifty-two cover (6%) textile industry as area of application in which **Chan Felix T.S (39)** consider textile industry as a fast changing market in which alternatives and criteria changes time to time and implemented them to solve the problem of supplier. **Chen Yuh-Jen (44)** identified strategy using strengths, weaknesses, opportunities and threats SWOT analysis and mathematical model. **Shaw Krishnendu (213)** selected the textile supply chain and highlighted the issues related to carbon emission and carbon house gas.

Watch Company:

Liao Chin-Nung (138) considered both tangible and intangible criteria to acquire multi aspiration levels and using linguistic variable instead of numerical values to give the accurate result. **Amin Saman (11)** selected best Internet Service

Provider (ISP) based on qualitative criteria and quantitative matrices and had discussed for a triangular fuzzy logic by considering three perspectives such as customer, performance, and competition. **Junyi Chai (111)** proposed believable rough set Business Rule Solutions (BRS) approach with criteria analysis, rough approximation, decision rule induction, and a scheme for rule application to validate the real supplier problem.

Paper Production Industry:

Kara Selin Soner (115) proposed supplier selection model in unknown environment by classifying the research phase into three categories such as pre-research phase, pre evaluation phase and evaluation phase to rank the potential supplier under qualitative data to overcome the issues of multi-product and multi-period.

Poultry Industry:

S. Nallusamy (162) proposed Agile Based Supply Chain Model for the Poultry Based Products which will integrate and increase the transparency among the stakeholders in the supply chain and eliminate the mediators and meet out the market demand, also the model when used for proper selection of suppliers, can considerably decrease production lead time, reduce manufacturing cost, increase customer satisfaction, and strengthen corporate competitiveness.

Electronic Industry:

Eight out of fifty-two articles (16%) cover the electronics as area of application in which **Chan F.T.S (38)** solve the decision problem related to manufacturers of sophisticated semiconductor assembly equipments with multi-item, multi-criteria for the development of supplier selection model. **Lee Amy (132)** describe the supplier selection problem as multi objective in nature of TFT-LCD manufacturer to evaluate the performance of manufacturer and weight of criteria is calculated, **Lee Amy (132)** also describe TFT-LCD manufacturers by incorporating benefit, opportunities, Cost and Risk (BOCR) as major criteria. **Onut Semih (176)** handled supplier problem in the telecommunication industry in GSM sector that includes both tangible and intangible factors relating to multi criteria decision making problem under the fuzziness. **Wu Desheng (256)** applies the Dempster–Shafer theory with grey related analysis to tackle the fuzziness of supplier problem by using both qualitative and quantitative data. **Chen Yueh- Hsiang (43) and Chen Ping (42)** discussed about the supplier selection problem in the area of electronic industries.

Computer Manufacturer:

Two out of fifty-two journals cover (4%) computer manufacturer as area of application in which **Chen Lisa (41)** developed best possible alternatives by providing rational systematically. **Deng (61)** highlights the issues with the integration of product line design and supplier selection simultaneously and Pareto optimal product line designs were determined.

Ink Cartridge Company:

Hou Jiachen (100) adopted mass customization environment to assist manufacturer to evaluate supplier selection problem for the procedure of product design and manufacturing and finds the issues like competitive priorities as one of the key factor for market survival.

Fertilizer Industry:

Rouyendegh Babak (202) considered uncertainty with complex multi criteria problem and proposed that by triangular fuzzy number, competitive advantage and long term relationship could be achieved.

Pharmaceutical Company:

Talluri Srinivas (232) evaluated the vendor performance variability measures related problem with nonparametric statistical technique by max-min approach to find out the maximum and minimum efficiency of vendor with flexible number of alternatives.

Logistic System and Postal Services:

Faeza, F. (70) proposed a model in fuzzy environment to find the order allocation and vendor selection by mathematical programming to achieve the buyer's demand and vendor capacity. **Qian Li (189)** proposed market-based strategy with increase or decrease in cost, delivery time, service level, or quality by analyzing through deterministic delivery time and stochastic delivery time and concept of lean manufacturing, cost reduction, flexible manufacturing, better delivery time and optimum service level were focused as per market strategies.

4.3.3 Observation and Analysis:

I have reviewed 52 journal articles published during last ten years on the basis of the area of application on solving supplier selection and evaluation problem. The following sub-section covers some observations based on these articles.

Most focused area of application:

The first objective of this paper was to find out the most focused area of application in the literature on supplier selection and evaluation. The automobile Industry being the most focused followed by manufacturing firm, electronics industry, textile industry, computer manufacturer, refrigerator plant, service company, steel industry, washing machine company, watch firm, fertilizer company, ink cartridge and logistic system.

Reliable papers are solving suppliers selection has seen in Table 4.7, automobile industry contributing 19% of articles, manufacturing firm contributing 19% of articles and electronics industry contributing 16% of articles. Most authors have found to be interested in developing individual model or integrated model related to supplier selection.

Table 4.7: Contribution of Papers

Area of Application	No. of Papers	Contribution
Manufacturing Firm	10	19%
Automobile Industry	10	19%
Airplane Industry	2	4%
Steel Industry	2	4%
Refrigerator Plant	2	4%
Railway Industry	1	2%
Raw material	1	2%
Washing Machine Company	1	2%
Textile Industry	3	6%
Watch Company	3	6%
Paper Production	1	2%
Poultry Industry	1	2%
Electronics Industry	8	16%
Computer Manufacturer	2	4%
Ink Cartridge	1	2%
Fertilizer Company	1	2%
Pharmaceutical Company	1	2%
Logistic System and Postal Services	2	4%
Total	52	100%

While airplane industry, computer manufacturer, refrigerator plant, logistics and service company and steel industry contributing 4% each, the textile industry, watch company contributing 6% each and remaining areas of applications contributing 2% each of the articles published on supplier selection and evaluation problem.

De Boer Luitzen (59) stated that supplier related problem is situation specific; it means that the criteria will be different for different area of application that is why it gets more realistic. Supplier selection model proposed by many authors in a specific area of application might be applied to another area may not be exactly applicable.

Environment of Area

The second objective of this article has been finding the area of environment. It means that in which situation the author solve the supplier related problem. This can be classified into two major decision criteria, deterministic and uncertainties situation. 33% of papers (17 out of 52) considered the uncertainties environment area and 67% of papers (35 out of 52) have considered the deterministic environment area while solving supplier problem and evaluation. Chai Junyi suggested in his review article that decision environment defined by uncertainties, decision goal and problem formulation. In studies of decision making, decision environment which does not involve directly or indirectly the uncertainties then it would be related to deterministic situations; otherwise, it is uncertainties area of environment. The categorization of decision situation is shown in Figure 4.11.

Mathematical model are the major decision technique by which the author tackles the deterministic type of decision environment and fuzzy set theory, stochastic programming, neural network handles the uncertainties situation of supplier problem.

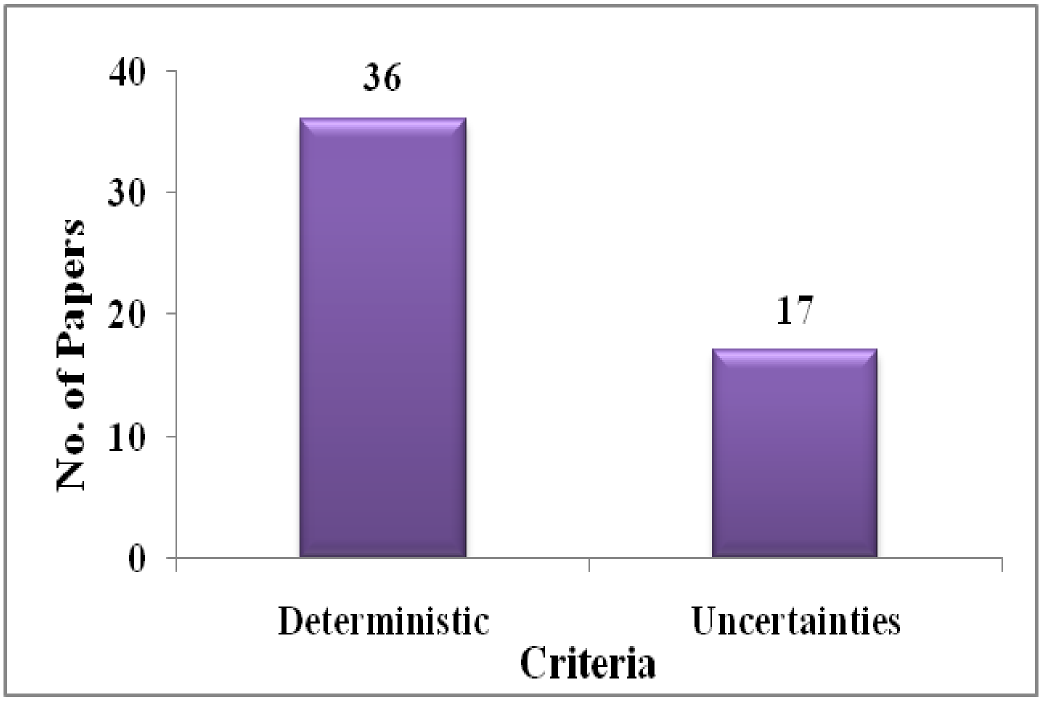

Figure 4.11: Decision Situations

4.3.4 Conclusions:

From a study made from 52 articles published during the last ten years a review was done on supplier selection and evaluation based on the area of application. Primarily it was observed that the most focused area to be automobile followed by manufacturing and electronics industry. From this study it was found that around 67% of research articles considered the deterministic environment of area and 33% of articles are considered uncertainties environment of area when solving the selection of supplier and evaluation problems. Next it was accepted that uncertainties to be more realistic and accurate decision environment than deterministic. This study has two limitations, one is that the systematic review has considered only last ten years articles and the second is that it focuses only on certain areas of application related to supplier selection and evaluation problem.

4.4 MCDM Tools Application for Selection of Suppliers in Manufacturing Industries Using AHP, Fuzzy Logic AND ANN

4.4.1 Problem Definition and Methodology:

In manufacturing industry selection of right supplier(s) is one of the challenging activities. Supplier selection is the method of determining the appropriate suppliers to provide the right quality of products, at the right quantities, at the right price in the right time. During the last ten years based on the changes in the business sector, Multi-Criteria Decision Making (MCDM) has been one of the fastest growing areas. By choosing the best supplier, the companies can increase their productivity and also achieve a competitive advantage. In the earlier periods, several methods have been proposed to solve the supplier selection problem, such as the linear weighting methods, the analytic network process, total cost approaches and mathematical programming techniques. Although the linear programming methods are simple, they are not accurate and more variations exist.

Hence in this research, the latest multi-criteria decision making tools such as Analytical Hierarchy Process (AHP), Fuzzy Logic (FL) and Artificial Neural Network (ANN) were deeply studied. While selecting the best supplier, many criteria are involved. The criteria may be different for different approaches. The decision makers always express their preferences on alternatives or on the attributes of supplier which can be used to help rank the supplier and choose the viable one. In this section, applications of fuzzy logic and AHP have been discussed with case-studies and also have presented the discussion on implementation of ANN for supplier selection.

4.4.2 Application of Fuzzy Logic Decision Making Method (FLDMM):

Decision making is an important social, economic endeavor for any organization. Decision making activities are the steps taken to choose a suitable alternative from those that are needed for attaining a goal. The prime domain for existing fuzzy decision making is uncertainty. There are several states under the decision making process. There may be situations when even though decisions made are good, the output may be adverse. When good decisions are made continuously for a longer period, advantageous situation would prevail.

Analysis using FLDMM:

In a car purchasing problem, a customer communicates with the sales person about the car attributes like price, mileage, comfort, maintenance cost, re-sale value and popularity in the following terms.

Price	: The price of the car is around US$ 20,000
Mileage	: Mileage will be around 20 km
Comfort	: Overall comfortability of the car is best
Maintenance	: Cost of Maintenance should not be very high
Re-sale value	: The re-sale value after 3–4 years should be OK
Popularity	: Popularity of the car is high

Here we consider three cars A, B and C and compare their price, re-sale value, mileage, comfort, maintenance and popularity. Comfort, maintenance and popularity are rated out of 10 point scale whereas mileage is taken in km/lit as given in Table 4.8.

Table 4.8: Car Data

Car	Price in US$	Re-sale Value in US$	Mileage in km/lit.	Comfort (Out of 10)	Maintenance (Out of 10)	Popularity (Out of 10)
A	18,000	8,000	16	8	6	9
B	22,000	9,000	17	8	8	8
C	25,000	12,000	20	9	7	7

Analysis was done by means of a graph for each criterion and their corresponding membership values were found. The membership values for each criterion with order of car (A, B & C) are as follows.

Price (1, 0.9, 0.7), Resale (0.8, 0.9, 1), Mileage (0.85, 0.95, 1), Comfort (0.9, 0.9, 1), Maintenance (0.8, 1, 0.95), Popularity (1, 0.9, 0.7). The final membership function for (A, B, C) is (0.8, 0.9 and 0.7).

Hence, Car B is the best from the given criteria.

FLDMM Features:

Fuzzy logic multi-criteria decision making was used in location planning for urban distribution centers under uncertainty. Also used in enhancing information delivery in extended enterprise networks. For example, to find the best supplier for mold and die manufacturing concern, the product price range, the information receiver's interest and the product range are often considered by the enterprises. In estimating anti-armor weapon fuzzy multi-criteria decision support procedure is applied to non-quantitative factors where decision making is complex.

4.4.3 Applications of Analytic Hierarchy Process:

Decisions involve many intangibles that need to be traded off. The AHP is a theory of measurement through pair wise comparisons and relies on the judgments of experts to derive priority scales. These are the scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments that represents, how much more one element dominates another with respect to a given attribute. The judgments may be inconsistent. How to measure inconsistency and improve the judgments, when it is possible to obtain better consistency is a concern of the AHP. The derived priority scales are synthesized by multiplying them by the priority of their parent nodes and adding for all such nodes.

Analysis using AHP:

Empirical case of the choice of logistics outsourcing suppliers - A company in the frozen food industry, specially established a team of experts who would be responsible for research and evaluate the feasibility of logistics outsourcing by comprehensive analysis. They decided to measure from A, B and C third-party logistics services in three preferred choice to solve the problem of logistics operation.

In the evaluation index system of logistics supplier, the top layer is the target to choose logistics outsourcing service suppliers, namely the first level evaluation index. The intermediate layer is the criterion and depends on the four secondary indexes like cost of logistics, operating efficiency and fundamental service quality and technology level of the logistic. To establish the three-level index by further subdivision, index of the intermediate layer model was framed and is shown in Figure 4.12.

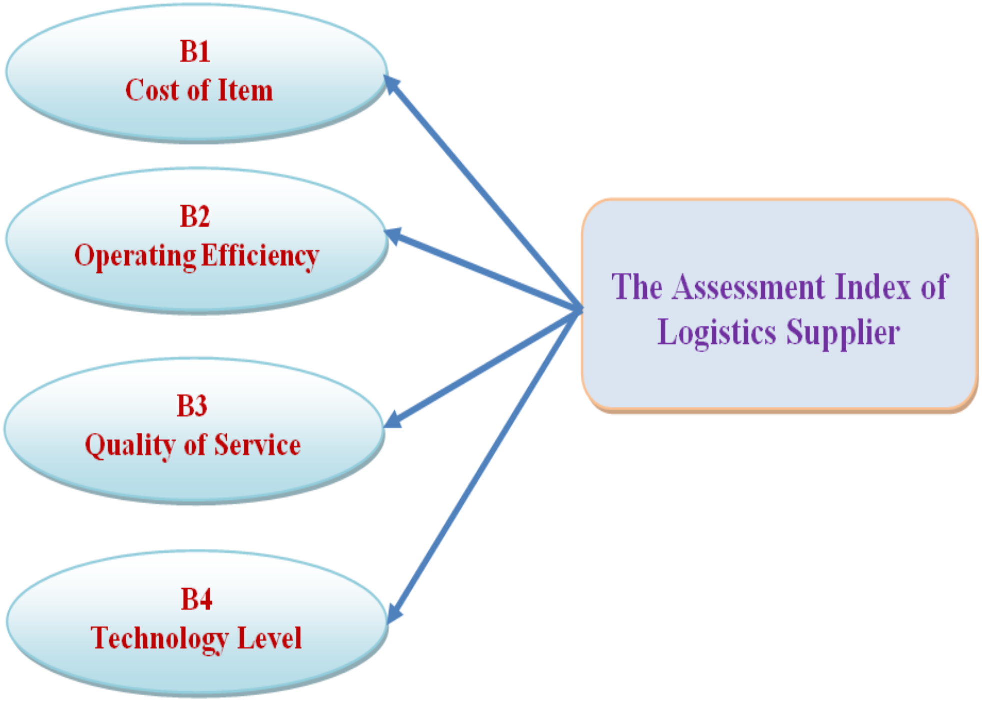

Figure 4.12: Intermediate Layer Index Model

Third party logistics company A as a state-owned enterprise logistics supplier, provides all directional logistics solutions to customers all over the country to delivery to the terminal or clients with the logistics branches in 24 hours. Its business scope involves transportation, warehousing, distribution and overall logistics packaging and design. Company A is the lowest logistics cost in 3 candidates enterprises, but the assignment speed is slower, and the prestige and transportation technology are relatively backward. Logistics Company B owns many professional companies in refrigeration, hotel, real estate, logistics and distribution, import and export trade. The transportation and warehousing logistics cost of Company B is the highest in three candidates enterprises, but the operation accuracy is general, the compatibility of enterprise is poor culture and the information technology is relatively backward. As one of modern refrigeration logistics enterprises, Logistics Company C is an integrated modern logistics enterprise specialized in the cold storage, distribution and information processing integration. Using modern information and network tools, the company provides goods transportation, storage, fresh goods and logistics distribution, etc. in a scientific and orderly logistics flow. The operation accuracy and readiness are the highest. And its logistics information technology is the most advanced. The judgment matrix of goals layer is given in Table 4.9.

Table 4.9: The Judgment Matrix of Goals Layer

Supplier	**B1**	**B2**	**B3**	**B4**
B1	1.000	2.000	3.000	2.000
B2	0.500	1.000	2.000	1.000
B3	0.333	0.500	1.000	0.500
B4	0.500	1.000	2.000	1.000

The criteria weights are (0.423 0.227 0.123 0.227).

The λ_{max} is calculated and is found to be $\lambda_{max} = 4.010$.

The Consistency Index CI is found by CI = λ_{max} -n)/ (n-1) = 0.003

From Saaty's scale, Random Index (RI) = 0.89

And the Consistency Ratio (CR) is found by CR = CI/RI = 0.004

Then the ranking alternatives for each parameter were found. The priority vector for B1 is (0.550, 0.210 and 0.240), B2 is (0.167, 0.333 and 0.500) for B3 is (0.333, 0.500 and 0.167) and for B4 is (0.333, 0.500 and 0.167). The best supplier is found by multiplying the priority vectors of B1, B2, B3 and B4 with the criteria weights.

$$\begin{pmatrix} 0.550 & 0.167 & 0.333 & 0.333 \\ 0.210 & 0.333 & 0.500 & 0.500 \\ 0.240 & 0.500 & 0.167 & 0.167 \end{pmatrix} \begin{pmatrix} 0.423 \\ 0.227 \\ 0.123 \\ 0.227 \end{pmatrix} = \begin{pmatrix} 0.387 \\ 0.339 \\ 0.247 \end{pmatrix}$$

Obviously, supplier A has the highest score in the three logistics outsourcing service suppliers and is the best choice.

AHP Features:

AHP is flexible, intuitive and checks inconsistencies. Since problem is constructed into a hierarchal structure, the importance of each element becomes clear. There is no bias in decision making. The disadvantages of AHP include irregularities in ranking, use of additive aggregation etc. So that some of the important information may be lost, also more number of pair wise comparisons is needed.

Analysis using AHP and FUZZY LOZIC:

Here a manufacturing industry is considered for analysis of supplier selection problem using AHP and FUZZY LOZIC. The collected input data are shown in Table 4.10.

Table 4.10: Input Data

Supplier	Total Shipment Received	% of Acceptance	% on Schedule	Cost Reduction Suggestions	Price/ Unit
A	100	90	80	1	40
B	60	80	90	1	50
C	50	70	100	3	60

AHP:

Pair wise comparisons are made between suppliers and also between criteria. The resultant weights for suppliers A, B & C are (0.362, 0.25 & 0.313). The maximum weighted supplier is A. Hence supplier A is selected.

Fuzzy Logic:

Using FUZZY, the membership function for (quality) percentage of acceptance is (1, 0.78 & 0.59), percentage on schedule (0.62, 0.81 & 1), cost reduction suggestions (0.6, 0.6 & 1), price per unit (1, 0.81 & 0.58)

$$\mu Di = \min (\mu (gi/ai))$$

Supplier having higher corresponding membership function will be selected

$$\mu D = \max (\mu Di)$$

According to this supplier A is having 0.62 membership function. Hence the supplier A is selected.

The Comparison between Fuzzy Logic and AHP is given in Table 4.11.

Table 4.11: Comparison between Fuzzy Logic and AHP

Sl. No.	AHP	Fuzzy Logic
1	AHP gives results through pair wise comparisons and relies on the judgments of experts to derive priority scales.	Fuzzy Logic belongs to the family of many valued logic. It focuses on fixed and approximate reasoning opposed to fixed and exact reasoning.
2	AHP takes values based on Saaty's scale to find the Consistency Ratio followed by Consistency Index (CI). $CI = (\lambda_{max} - n)/(n-1)$	A variable in fuzzy logic can take a truth value range between 0 and 1, as opposed to taking true or false in traditional binary sets. Since the truth value is a range, it can handle partial truth.
3	AHP also tries to give the definite decisions and is unambiguous.	FL provides a method to make definite decisions based on imprecise and ambiguous input data.

4.4.4 Clarification of Problem:

AHP is used in this article because it draws a relationship between the criteria themselves through pair wise comparisons. Also AHP is the best evaluation index system which is needed to rank the suppliers. However a fuzzy environment prevails in the industry in the selection of supplier. The decision makers compose judgments and an uncertainty can occur. So a fuzzy set is required to give answer for uncertainty. ANN is another kind in its way such that it has a special learning feature and weights are calculated by assumption. It does not need the help of an expert or a fuzzy integration method.

An artificial neural network is an information processing system that has certain performance characteristics in common with biological neural networks. Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology based on some of the assumptions. A neural network is characterized by neurons, method of determining the weights also called training the neuron and its activation function. Each neuron is connected to other neurons by means of direct communication links, each with an associated weight. Each neuron has an internal state called its activation state or activity level which is a function of the inputs it has received. For example, if a neuron Y has three inputs x_1, x_2 and x_3 and the weights on the connections from the inputs to the neuron Y are w_1, w_2 and w_3 respectively, the net input y_in is found by

$$y\_in = w_1x_1 + w_2x_2 + w_3x_3$$

ANN Features:

Decision making process in the tourism sector such as choosing the location from several alternatives of a hotel using past data and applying one or more ANNs to forecast probable future socio-economic data to arrive at the best alternative or choosing the most convenient marketing plan by creating a projection of the future socio-economic data. Also it is used in strategic decision making processes in a political, economic and social context. Further, ANN, AHP and fuzzy logic can be utilized to create a supplier selection model separately but their modelling mechanisms and performances are quite different and a comparison is needed to choose the best supplier.

4.4.5 Conclusions:

In the earlier papers the selection is made by limited categories or criteria. This paper has made an attempt to present the applications of MCDM tools of fuzzy logic and AHP with same example. This case study represents the use of AHP and fuzzy logic in supplier selection with same results. The case study for AHP is a logistics outsourcing problem of tinned foods in which the criteria such as cost, operating efficiency, and service quality and technology level are taken and a pair wise comparison is drawn. The features of Fuzzy logic and AHP along with their merits and demerits have been presented separately. An example on selection of car is made using FLDMM whereas in AHP an example on selection of best supplier was made using pair wise comparisons and Saaty's scale. In the selection of car, we took some criteria such as price, resale value, mileage, comfort and maintenance. Then three cars A, B and C were chosen and their price, resale value, mileage, comforts and maintenance data are collected. Also customer's view and perception on price, resale values were considered. In addition the same example of supplier selection was also taken using AHP and Fuzzy Logic. Also efforts were made to apply ANN for the selection of supplier. The result gives a suggestion to decision makers in the company in deciding to select a supplier. In future a supplier selection in a manufacturing industry for choosing the best supplier ANN, AHP and Fuzzy Logic may be used separately.

4.5 Selection and Evaluation of Supplier through Hybrid Data Envelopment Analysis Decision Model

4.5.1 Problem Definition:

Selection of the right suppliers in the supply chain drastically reduces the costs of purchase and improves the competitiveness of corporate price. Now a day the importance on quality and delivery time plays a major role in globally competitive market. Most of the companies are investing considerable amount from their revenues on inventory. The selection problem of supplier involves multiple contradictory issues that are tangible and intangible. Thus the purpose of this study is to propose an integrated decision model of hybrid Data Envelopment Analysis (DEA) for selection and evaluation of supplier.

4.5.2 Methodology:

In this section of study by using data envelopment analysis the best supplier is selected and the proposed model has been developed and shown in Figure 4.13. It can be used to estimate the efficiency of a number of producers, generally referred as Decision Making Unit (DMU). Data Envelopment Analysis model compares each producer with only the "best" DMU in the group, which is better than the comparison with the average of the group. In DEA, we can consider number of DMUs, each of them consuming similar inputs to produce the varying level of outputs.

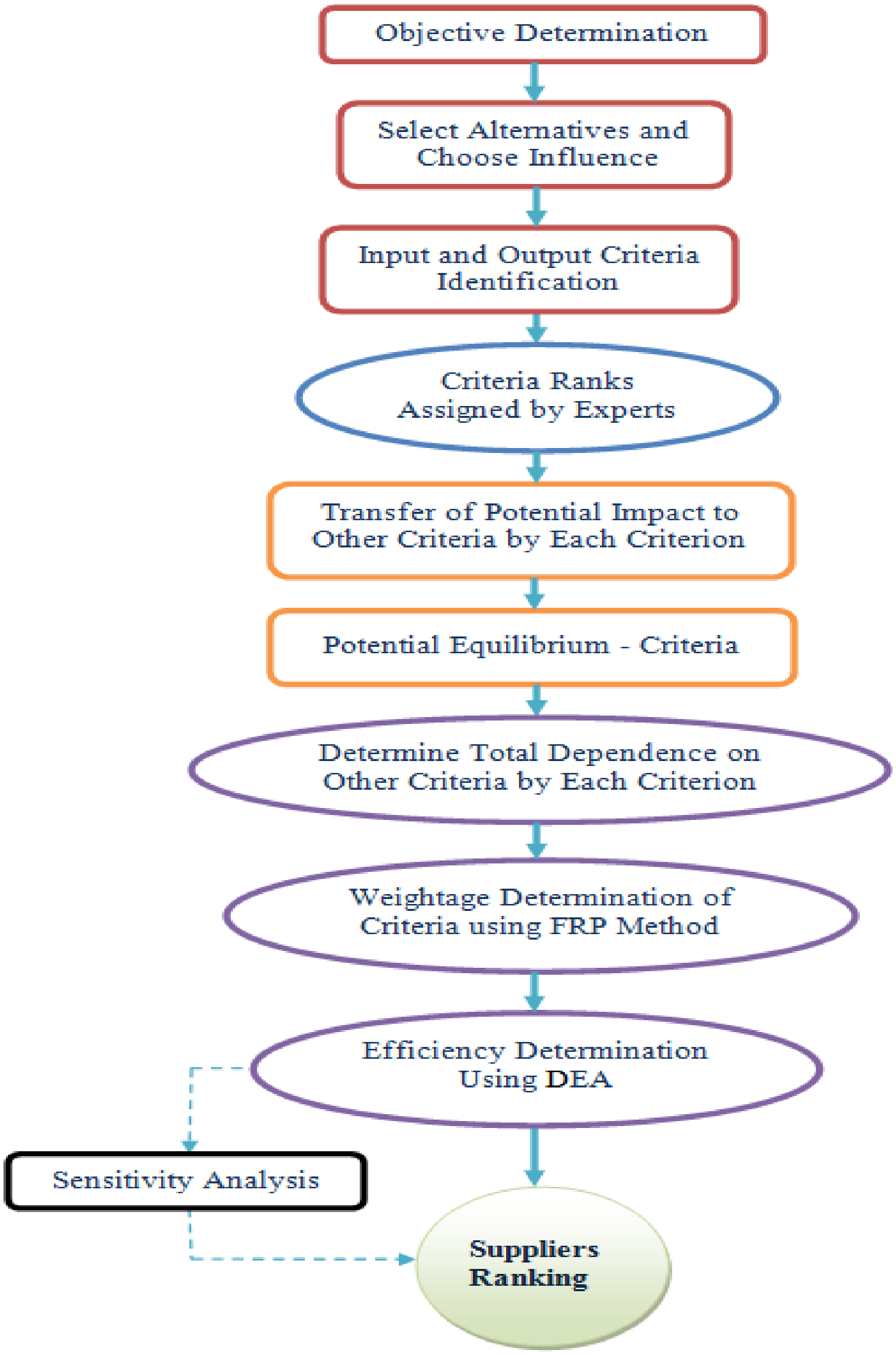

Figure 4.13: Proposed Model

A fundamental assumption behind this method is that if a given DMU, is capable of producing units of output with inputs, then other DMUs shall also be able to do the same if they were to operate efficiently. Similarly, if DMU is capable of producing units of output with inputs, then other DMUs should also be capable of the same. DMUs and others may be combined to form a composite producer i.e. virtual producer with composite inputs and outputs. The emphasis of DEA is on finding the "best" virtual producer for each real producer. Figure 19 gives the detail frame work for the supplier selection. DEA was used to evaluate the performance of hospitals, universities, transport sectors, business organizations etc. A general mathematical formulation is needed to handle the case of multiple inputs and multiple outputs. This mathematical formulation was provided [15]. Let us use x and y to represent inputs and outputs, respectively. Let the subscripts i and j to represent particular inputs and outputs respectively. Thus xi represents the i^{th} input, and y_j represent the j^{th} output of a decision-making unit. Let the total number of inputs and outputs be represented by I and J respectively, where I, J > 0. In DEA, multiple inputs and outputs are linearly aggregated using weights. Thus, the virtual input of a firm is obtained as the linear weighted sum of all its inputs given in equation (10).

$$\text{Virtual Input} = \sum_{i=1}^{j} u_i\, x_i \qquad \text{-- (10)}$$

Similarly, the virtual output of a firm is obtained as the linear weighted sum of all its outputs given in equation 11.

$$\text{Virtual Output} = \sum_{j=1}^{j} v_i\; y_i \qquad \text{-- (11)}$$

Gives the virtual input and outputs, the Efficiency of the DMU in converting the inputs to outputs can be defined as the ratio of virtual outputs to inputs given in equation 12.

$$\text{Efficiency} = \frac{\text{Virtual Output}}{\text{Virtual Input}} \qquad \text{-- (12)}$$

$$\text{Efficiency} = \frac{\sum_{j=1}^{j} v_j y_j}{\sum_{i=1}^{j} u_i \, x_i}$$

Where,

i = 1, 2, 3….. I are inputs, j = 1, 2, 3….. J are outputs, s = 1, 2, 3….. N are DMUS

u_i = weight of i^{th} input,

v_i = weight of j^{th} output

x_{is} = amount of the i^{th} input for s^{th} DMU,

y_{js} = amount of the j^{th} output for s^{th} DMU

In this article a new weight determining method of Factor Relationship Parameter (FRP) was used to compute the weights of each criterion. FRP method for determining the criteria weights in multi criteria decision making environment. First the potential impact of the criteria is determined using equation (13).

$$P = S\,(m - 1) \qquad \text{-- (13)}$$

Where,

P = Potential of the system's criterion impact

S = Maximum value of the scale of evaluation used (Table13)

m = Number of the system's criteria.

Next criteria are ranked by the experts based on their importance. Then the relationship between the criteria is determined based on the rank and given in Table 4.12. The procedure is as follows: the criterion of a lower rank has the smaller impact on the criteria having higher ranks and therefore it should transfer a larger part of its potential impact to them.

Table 4.12: Scale of Quantitative Evaluation of Interrelationship between the System's Criteria

Sl. No.	Type of Effect Produced	Rating of Effect Produced by Interrelationship (in points)
1	Almost none	1
2	Very Weak	2
3	Weak	3
4	Lower than Average	4
5	Average	5
6	Higher than average	6
7	Strong	7
8	Very Strong	8
9	Almost absolute	9
10	Absolute	10

The impact of the criteria a_i on the main criterion is determined and then this impact is transformed using the following equation (14).

$$a_{1i} = S - \tilde{a}_{1i} \qquad \text{-- (14)}$$

Where,

a_i = the impact of i^{th} criterion on the first main criterion

$\tilde{a}_i$ = the part of i^{th} criterion's potential impact transferred to the main criterion

The total impact of any criterion as well as the consistency level of a subset may be determined based on the data provided in the form of matrix. The subset considered in the matrix is consistent and stable if the total impact of its criteria with a positive sign is equal to their total impact with a negative sign, i.e. their sum is equal to zero. Next the total impact Pi is calculated using equation (15).

$$Pi = \sum_{i=1}^{m} aij,\ \ j \neq i \qquad \text{-- (15)}$$

After that, the total potential, required for determining the criteria weights, will be calculated based on the data presented in the first row of the matrix, thereby making the filling of all other rows of the matrix unnecessary. The following equation (16) is used for determining the total potential.

$$P_i = P_1 - m.\ a_{1i}, \qquad \text{-- (16)}$$

Where,

Pi = the total impact (dependence) of the i_{th} criterion.

Finally the criteria weights can be determined using equation (17).

$$w_i = \frac{P_i^f}{p_s} = \frac{P_1 - ma_{1i} + s(m-1)}{ms(m-1)} \qquad \text{-- (17)}$$

Where,

PS = Total potential of a set of criteria which is found using equation (18)

$$P_S = m.\ P = mS\ (m - 1) \qquad \text{-- (18)}$$

P_i^f = Actual total impact of the i^{th} criterion of the system which is calculated using equation (19)

$$P_i^f = P_i + P \qquad \text{-- (19)}$$

Where,

P_i = Total impact produced by the i^{th} criterion of the system or its total dependence on other criteria.

4.5.3 Case Study:

The case study was performed in an automobile industry which is located in outer Chennai of Tamilnadu. The supplier selection model was developed based on five suppliers called S1, S2, S3, S4 and S5 with five evaluating factors, that includes three inputs and two outputs namely Delivery (D) in days, Capacity (Ca) in units, Warranty (W) in number of days, Cost (C) in rupees and Quality (Q) in percentage of acceptance respectively. The Table 4.13 shows the data of suppliers and the corresponding inputs and outputs.

Table 4.13: Data sets of Inputs and Outputs

Suppliers	Inputs			Outputs	
	D	Ca	W	C	Q
S1	12	170	28	2439	0.87
S2	11	240	19	2467	0.89
S3	13	260	20	2600	0.90
S4	10	260	24	2800	0.96
S5	12	270	17	2210	0.88

The weights of the attributes are calculated by using FRP method using the equations (4) to (10). The weights are shown in Table 4.14.

Table 4.14: Attribute Weights

Criteria	Inputs			Outputs	
	Delivery	Capacity	Warranty	Quality	Cost
Weight	0.160	0.510	0.330	0.628	0.372

Then DEA efficiency is calculated for all the suppliers by using equation 3 and the corresponding values are given in Table 4.15.

Table 4.15: Efficiency of Suppliers

Suppliers	Efficiency	
	Using FRP	With Equal Weights
S1	75.84	64.55
S2	82.29	66.34
S3	77.95	63.88
S4	91.98	72.45
S5	78.16	61.67

From the above Table, it is noted that supplier 4 with higher efficiency is selected as best supplier. So that for this case study supplier 4 is taken as best supplier. The following Figure 4.14 represents the DEA Efficiency of all the suppliers.

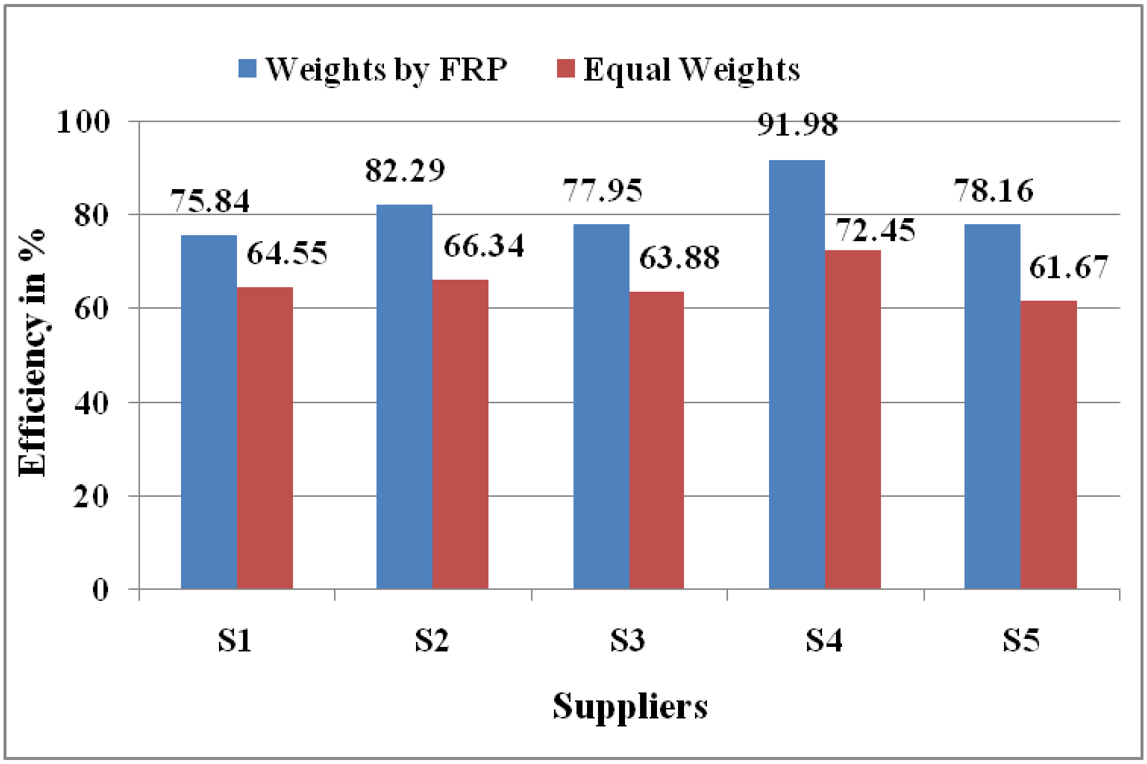

Figure 4.14: DEA Efficiency

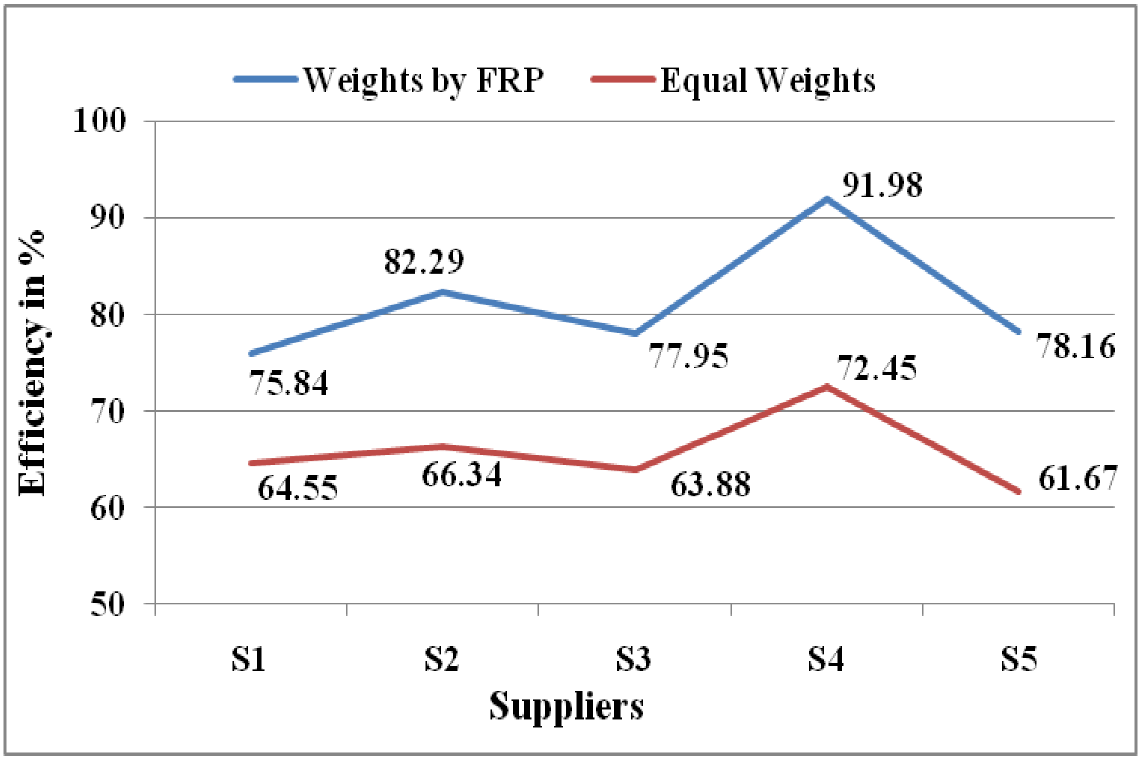

Figure 4.15: Sensitivity of the DEA Model

Sensitivity analysis is used to determine how the model is "sensitive" during the changes in the value of the parameters of the model and in structure of the model. It is performed to do a trade off study and to check the strength of the model. In sensitivity analysis the values of any one input parameter could be changed and the changes in output performance measured. In this study equal weights were assumed for the criteria and the efficiency was observed. The result of the sensitivity analysis is given in the above graphical representation of Figure 4.15. From Figure 4.14 it is observed that the ranking of the suppliers is not changing and hence the robustness of the proposed model is proved.

4.5.4 Conclusions:

Decisions of evaluation and selection of a supplier is an important part of supply chain management. In present intense competition, producing high quality products with minimum cost without satisfaction of suppliers is not possible. From this work based on DEA a multi-criteria decision making model for selection of the best supplier was developed. For which multiple criteria like quality, delivery, cost, capacity and warranty were considered. And the weights of the criteria were computed using FRP technique. The results were compared and finally the robustness of the developed model was also checked by sensitivity analysis. This model gives a reliable result and it can be extended for the same kind of industries.

This proposed model can be more flexible to accommodate the qualitative and quantitative criteria for supplier selection. DEA can help to evaluate and compare suppliers in different evaluation criteria which can offer a more robust tool to select and evaluate suppliers based on both the above criteria.

4.6 Sustainable Green Lean Manufacturing Practices in Small Scale Industries - A Case Study

4.6.1 Problem Statement:

Small scale industries are facing a lot of resource constraints such as electricity, water, etc. Due to power cut problems and labour problems they need effective methods to cut down the cost and move towards pollution free manufacturing. This research article tries to identify a simple method called as Eco-Value Stream Mapping combining both lean and green techniques to reduce waste and that gives an impact on environment.

4.6.2 Methodology:

The various steps involved in the research methodology for lean and green techniques are shown in the following Figure 4.16. Its starts with TAKT time calculation followed by total time calculation. Based on the present scenario the present state of VSM has been drawn to mention the impact of environment of each process. To reduce the pollution the survey method bench marking process was used during VSM process. The future state of VSM has been made for checking about the practical applications of echo VSM after the improvement process. So, after implementing the future state VSM the study of the product flow has been carried out to observe the process in manufacturing. Based on that, the time study was also made to determine the cycle time of every operation. Finally, the wastes were identified and the ways to reduce the wastes were also identified.

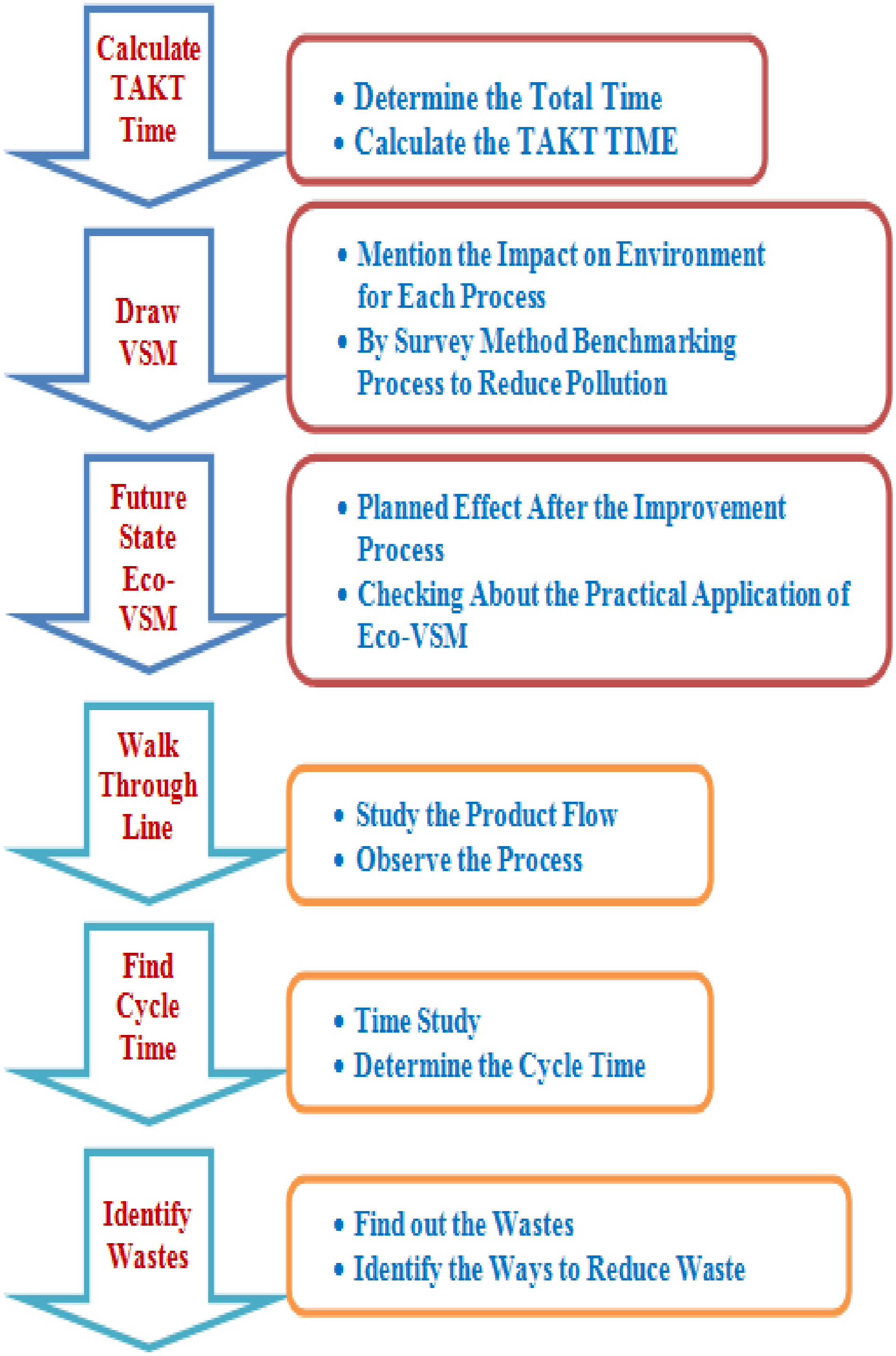

Figure 4.16: Research Methodology Block Diagram

4.6.3 Case Study:

The technique of total green manufacturing combines lean and green practices. It ensures complete utilization of all resources and a green product from design to recycling of the product. Make to order concept is applied. All the processes are effectively coordinated so that the customer gets the product at the earliest time possible. By elimination of all wastes leanness is practiced. Pull production, Value Stream Mapping (VSM), Just in Time (JIT) and Supplier Maintained Machines (SMM) are the techniques used. SMM is adapted to all machines bought for the new plant. The machineries are maintained in good working condition by proper scheduled maintenance methods.

Whenever the new machines are installed, the supplier takes care of complete maintenance for 10 years under automatically renewed annual maintenance contract. Under this method all the spare parts, consumables for smooth running of the machineries are supplied by the Original Equipment Manufacturer (OEM). By this method inventory will not wait for want of machine, operators are trained well. Products are redesigned in such a way that materials selection, process parameters, easy distribution, safe recycling of components of the product at the end of useful lifecycle are totally green. From design, manufacturing, distribution to consumer, to the disposal of the product all are decided after considering several alternating Environmental Impact Index (EII). It is calculated under each stage and the environmental impact would be minimum. By good quality of raw materials and sub components, the end life of product recyclability is achieved without dumping as waste. The various steps involved in calculating the EII in green manufacturing is shown in Figure 4.17.

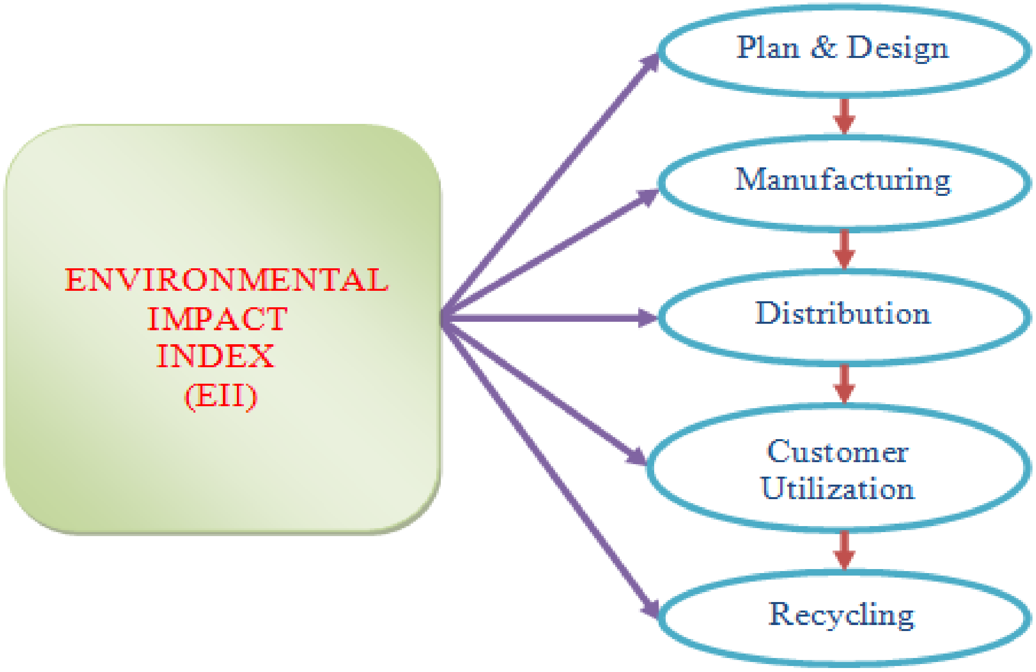

Figure 4.17: Total Green Manufacturing

Zero defects and rework, [through high quality tools, reliable machineries and processes trained operators], single piece flow, Single-Minute Exchange of Die (SMED) leads to continuous flow. Process chain analysis, eco route map are applied. A Value Stream Map is drawn by finding the cycle time for each process and the environmental effect is also noted. By identifying the wastes, future state map is drawn with improved processes to reduce the wastes. Different ideas are generated to develop for reducing wastes by Brain storming technique. A survey is conducted to find the best method of Benchmarking for reducing the pollution. The methodology is used with different types of small scale industries like fabrication, textile, food and service workshops.

Some of the following small scale industries are taken for case study and are shown in Table 4.16. There are five employees working in the mechanical fabrication industry. One person does the marking and gas cutting. Two persons are deployed for drilling, setting and welding. Two persons are working for grinding and painting. Generally all materials are supplied to the industry in the morning. Products are produced and dispatched in the evening of the same day. The factory follows Just-in-Time already. Goods are manufactured only by customer order. During the change of product, setting will take more time. A well structured questionnaire is circulated among the local small scale industries of this similar type to get ideas for Green Manufacturing. From the questionnaire survey, all the employees' knowledge is gathered and Bench marking is done to find the best idea followed by the leading competitor.

Table 4.16: Survey Results

Sl. No	Type of the Industry	No of Respondents	Suggestions	Remarks
1	Automotive Industries	5	To Train Operators for Creating Awareness About Green Manufacturing	Cost to be Estimated
2	Seat Fabrication Industries	5	To use Welding Booths to Control Pollution	Economic Analysis to be Done
3	Automobile Service Workshops	4	Smoke to be Properly Exhausted	-
4	Painting Shop	4	To use Painting Booths with Pollution Control Equipments	Viability Study to be Conducted

As per the suggestions from the employees of various industries the following observations were made. In fabrication industry welding process is advised to be done in a closed chamber with proper exhaust control system instead of in an open area. Similarly in automobile service workshops the smoke is to be properly exhausted. A paint booth is recommended to reduce air pollution. Some of the respondents shared their ideas for using eco friendly points. Also it was suggested for producing electric power on the roofs of the industry to provide 300 KW Photo Voltaic Power Plant.

4.6.4 Conclusions:

The system on green lean infrastructure gives out a channel for the successful implementation of lean green best practices and achievement of corresponding green results. From the above survey it was clearly found that there is tremendous scope for the implementation of the lean green methodologies in small scale industries to save the resources and avoid polluting the earth. Uniformly suggestions were received from all the industries to produce electric power by using solar panels on the roofs of their industry. By analyzing the impact on environment simultaneously with lean value stream, mapping wastes, pollution could be reduced. The improvement of green lean manufacturing is a continuous process. The incentives to the small scale industries and measures for clean technologies by the government are probably the other way to advance an energetic green wealth. Other tools of lean like Kaizen, Kanban and SMED also can be combined together.

4.7 Environmental Sustainability Evaluation for an Automobile Manufacturing Industry using Multi-Grade Fuzzy Approach

4.7.1 Problem Definition:

From the outlook of environmental performance assessment the literature was examined, sustainability estimation and applications of multi-grade fuzzy approach to develop theoretical model for environmental sustainability. For evaluating environmental sustainability a proposed methodology was developed with necessary indicators like multi-grade fuzzy approach etc. The fuzzy approach assesses environmental sustainability index and provides possibility for development. A case study of an automobile manufacturing industry was evaluated. Few numbers of researchers only have explained their attention towards the drivers, barriers, and pressures of Environment Management System (EMS) and GM. But drivers put fair impact on GM and various studies in the past have identified the number of drivers for green manufacturing. Green and sustainable manufacturing with eco-innovation together explain the impact on company sustainability performance as shown in Figure 24. Eco-innovation is again divided into four sub-divisions like eco-process, eco-product, green technological and green managerial novelties. These are very vital for sustainable development of manufacturing industry due to increasing environmental pressure.

The criteria, enablers and attributes pertaining to environmental sustainability were chosen based on the study and also to identify appropriate manufacturing industry for conducting the study. The data related to the theoretical model were collected from the experts who work in the pertinent area in the manufacturing industry. The experts acquire wide knowledge and experience in environmental sustainability and are involved in the process of implementing environmental sustainability practices.

4.7.2 Methodology:

After data collection, Multi-grade fuzzy approach was applied for calculating the Environmental Sustainability Index (ESI). After computation of the Environmental Sustainability Index, the grade pertaining to the score was found out and enhancement actions that would improve the ESI were proposed with. Finally enhancement actions were planned and initiated. The methodology followed for using Multi-grade Fuzzy Approach during this study is shown in Figure 4.19.

Figure 4.18: Framework for Green Manufacturing

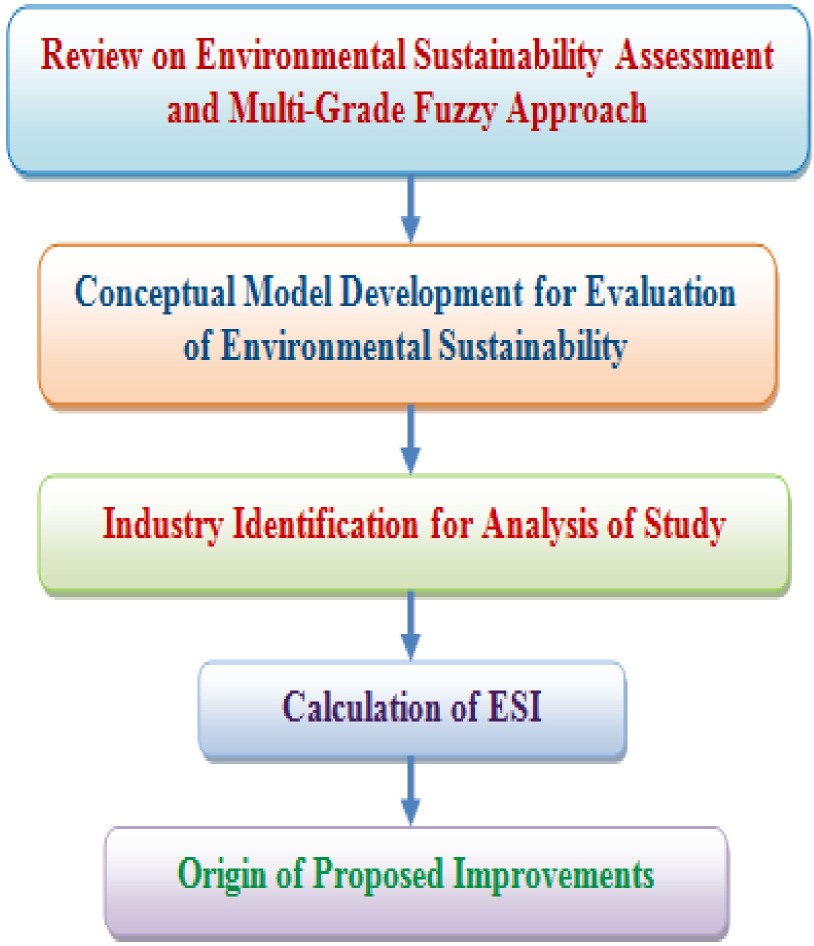

Figure 4.19: Multi-grades Fuzzy Approach Methodology

Development of Conceptual Model:

The environmental sustainability evaluation system was framed by thorough literature analysis. The assessment system consists of three levels. 1) Environmental Sustainability Enabler, 2) Five Environmental Sustainability Criteria and 3) 15 Environmental Sustainability Attributes. The theoretical model is shown in Table 4.17. The criterion, emission of pollutants refers to the overall emissions emitted during the manufacturing process which comprises two attributes namely solid waste emission and lifecycle global warming potential. The criterion, resource consumption refers to the usage of resources consumed by the industry during manufacture of the product. The attributes for resource consumption includes material, water and energy consumption. Environmental Impact criterion refers to the extent of impact created on the environment due to the manufacturing process. It has two attributes namely mass of restricted disposals and noise level generated at the workplace. The criterion, waste minimization and recycling include the measures taken by the manufacturing firm to minimize the wastes and to manufacture products that can be recycled. It includes two attributes namely ability to minimize waste and product recycling. The criterion, green product manufacturing refers to the efforts taken by the manufacturing firm to produce eco-friendly products. It includes attributes proportion of biodegradable materials and comprehensiveness of eco standard test report. These criteria and attributes encompass the conceptual model for environmental sustainability assessment.

Table 4.17: Theoretical Model for Environmental Sustainability Assessment

Enabler	Criteria	Characteristics
Environment	Emission of Pollutants	Solid Waste Emission
		Lifecycle Global Warming Potential
	Consumption Resources	Material and Water Consumption
		Energy Consumption
	Environmental Impact	Mass of Restricted Disposal
		Noise Level Generated
	Waste Minimization and Recycling	Ability to Minimize Waste
		Product Recycling
	Green Product Manufacturing	Proportion of Biodegradable Materials
		Comprehensiveness of Eco Standard Test Report

4.7.3 Case Study:

The study has been conducted in an automobile manufacturing industry located near Chennai, India. The industry has implemented certain sustainability and eco friendly manufacturing practices. The industry management takes more interest towards environmental sustainability assessment which would enable to develop their performance level.

Environmental Sustainability Index Evaluation Using Multi-grade Fuzzy Approach:

The Environmental Sustainability Index (ESI) of an industry is the product of overall assessment factor R and overall weight W. The equation for leanness index is given by,

$$ESI = W \times R \qquad \text{-- (20)}$$

The evaluation has been divided into five grades since every environmental sustainability factor involves fuzzy determination. Therefore ESI={10, 8, 6, 4, 2} where, 8–10 represents Extremely Environmental Sustainable, 6–8 represents Strongly Environmental Sustainable, 4–6 represents Fairly high Environmental Sustainable, 2–4 represents Fairly low Environmental Sustainable and less than 2 represents Poorly Environmental Sustainable. In this study five experts were considered for ratings and weights. The experts are presently heading various departments of an industry and possess rich knowledge and experience. The single factor assessment and weights provided by the experts are given in Table 4.18.

Primary Evaluation:

The calculation pertaining to emission of pollutants is shown as follows

Weights pertaining to emission of pollutants criterion are W_{11}= (0.4, 0.6)

Assessment vector pertaining to 'emission of pollutants' criterion is given by,

$$R_{11}=\begin{bmatrix} 7 & 6 & 5 & 6 & 5 \\ 6 & 7 & 6 & 7 & 6 \end{bmatrix}$$

Index pertaining to emission of pollutants criterion is given by,

$$ESI_{11}= W_{11}\times R_{11} \qquad \text{-- (21)}$$

$$ESI_{11}= (6.4, 6.6)$$

Using the same principle, the index pertaining to various Environmental Sustainability criteria have been derived.

$$ESI_{12}= (5.4, 6.6)$$
$$ESI_{13}= (5.7, 5.3)$$
$$ESI_{14}= (6.4, 6.6)$$
$$ESI_{15}= (6.5, 5.5)$$

Table 4.18: Single Factor Assessment and Weights Provided by Experts

ESI_i	ESI_{ij}	ESI_{ijk}	R_1	R_2	R_3	R_4	R_5	W_{ij}	W_i	W
ESI_1	ESI_{11}	ESI_{111}	7	6	5	6	5	0.4	0.2	1
		ESI_{112}	6	7	6	7	6	0.6		
	ESI_{12}	ESI_{121}	6	5	6	5	6	0.5	0.2	
		ESI_{122}	7	6	7	6	7	0.5		
	ESI_{13}	ESI_{131}	6	5	5	4	5	0.6	0.2	
		ESI_{132}	5	6	7	6	7	0.4		
	ESI_{14}	ESI_{141}	7	6	6	7	6	0.5	0.2	
		ESI_{142}	6	7	6	7	6	0.5		
	ESI_{15}	ESI_{151}	6	7	7	6	5	0.4	0.2	
		ESI_{152}	6	5	5	6	5	0.6		

Secondary Evaluation:

The calculation pertaining to Environment Enabler is given by

$$ESI_1 = W_1 \times R_1 \qquad \text{-- (22)}$$

Weights pertaining to environment enabler are given by

Overall weight W_1 = (0.2, 0.2, 0.2, 0.2, 0.2)

$$\text{Overall Assessment Vector } R_1 = \begin{bmatrix} 6.6 & 6.4 \\ 5.4 & 6.6 \\ 5.7 & 5.3 \\ 6.4 & 6.6 \\ 6.5 & 5.5 \end{bmatrix}$$

Environmental Sustainability Index

$$ESI = W \times R \qquad \text{-- (23)}$$

ESI_1 = (6.12, 6.08)

Tertiary Evaluation:

The value of Environmental Sustainability index of the firm has been computed as follows

Overall Weight (W) = 1

Overall Assessment Factor = 6.12 & 6.08

ESI = (6.12+6.08) / 2

Therefore ESI = 6.1 ϵ (6, 8)

4.7.4 Results and Discussion:

ESI was calculated using multi-grade fuzzy approach based on the Environmental Sustainability evaluation for an automobile manufacturing industry and found to be 6.1. This signifies that the company follows environmental friendly manufacturing practices and within the group of Strongly Environmental Sustainable falls in the acceptable level of 6 to 8. The results are very much matched with practical environment as the company implemented strategies such as 5S, ISO 9001:2008 QMS and ISO 14001 EMS. Some of the areas identified for improving the Environmental Sustainability of the company are as follows:

1) The company must come up with new technologies to manage sustainable design of green products to augment the eco performance and to minimize wastes occurring in manufacturing stages. Integrated product design applications must be incorporated while designing to deliver an eco-friendly product.
2) Emissions causing air pollution and generation of greenhouse gas must be restricted. The company must strictly adhere to the emission norms and must periodically evaluate the emissions.
3) The usage of non-biodegradable materials and toxic materials exceeding the requirement must be restricted. Eco standard test reports for the materials being used must be maintained and the material should be restricted from usage.
4) The company must allocate cost for adopting proper disposal methods and to develop techniques to support remanufacturing. Mass of the disposed consumables must be low and proper disposal method must be followed to dispose them
5) The manufacturing process must support two techniques of recycling and remanufacturing to improve its green performance. The proposed

development action helps the manufacturing industry to improve its green performance and also to better its ESI.

4.7.5 Conclusions:

Environmental dimension of sustainability needs main concentration. Sustainability is an essential idea for attaining competitiveness. Environmental Sustainability Index was calculated in this article for an automobile manufacturing industry using multi-grade fuzzy approach. The ESI of the company was found to be 6.1 and upgrading actions were proposed for further development. Green Manufacturing is an idea for reduction in raw material cost, safety expenses, environmental pollutant and increase in production efficiency. The above study analysis facilitated performance assessment of an environmental sustainability system and subsequent investigation. In order to develop the environmental sustainability of the company, development areas were recognized. On execution of the proposed augmentations, the environmental sustainable performance of the industry could be enhanced.

5.0 Discussion

Supply chain management integrates the business partners for the flow of raw materials to finished product delivery to the end user and also the information such as forecast, order from market to the supply chain partners. Accurate information is necessary to optimize material flow through successive steps of procurement, operations and distribution across the supply chain. Demand chain management focuses on marketing, sales and service part of the value proposition using more reliable, accurate and detailed information about consumer behavior. Demand uncertainty and the error in forecasting have a considerable impact on the supply chain.

Effectiveness of any supply chain is dependent upon the visibility that can be gained from materials flow, inventories and demand throughout the chain. But in demand chain to keep minimum inventory, materials flow is controlled by daily consumption from the suppliers to customer through manufacturing and also guarantees the availability of goods. Significant aspect in DCM is continuous demand information sharing at all the levels of operations, from distribution to suppliers via manufacturing.

To meet pull type of material flow in demand chain productivity, each and every part of the chain are monitored and improved, which ultimately lead towards effectiveness i.e. customer satisfaction.

Generalized form of CLSC structure with initial inventory at manufacturing plant, distribution site, retailer site and final end period inventory with various demand of product was proposed. During the numerical investigation a case was taken where the model had one product and each product was made using three different parts. Two units of part A, one unit of part B, one unit of part C were required to manufacture the product. In this research work IBM ILOG CPLEX Optimization studio v.12.5 was been used to get the optimal solution. The IBM ILOG CPLEX Optimization studio was designed for modelling linear, nonlinear and mixed-integer optimization problems and the systems were useful for large and complex problems. The cost related parameters were formulated.

In order to validate the proposed model, sensitivity analysis was performed. In this analysis, we had fixed the various percentages of commercial returns (z) and studied the impact on profit for various set of time periods (t) versus maximum profit. From the results, it was found that, the profit had remained over a line for time period $t<15$. There was a sudden fall in profit $t>15$ irrespective of the percentage of commercial returns due to the high cost at reverse loop.

During this analysis, we had fixed the various percentages of products sent to repair site (Xj) and studied the impact on profit for various set of time periods (t) versus maximum profit. From the results, it was observed that there was not much difference in maximum profit for Xj > 60 % irrespective of the various time periods. Also, we had fixed the various percentages of commercial returns (z) and studied the impact on profit for maximum capacity of disassembly site versus maximum profit. From the results obtained, it was found that there was a decrement in profit at the point where the maximum capacity of disassembly site was 600 and following linear increment in profit in the event of increasing the maximum capacity of the disassembly site.

Supply chain and logistics efficiency measures the performance of logistics and supply chain in firms from the characteristics of external outputs by the above mentioned design of score card and these outputs are rooted in enterprise business process. In score record, design and execution as well as applications of information technology in industries are the main signs to measure the performance of supply chain and logistics. These business processes involved in logistics and supply chains management exist in an industry or are to be carried out in an industry, but are not impacted by company policies and culture. Also confirmatory factor analysis shows that there is a strong correlation between design and execution and applications of information technology. To sum up, the structural model between policies and firm coordination, design and execution, effectiveness of shipment and applications of information technology can be established. The model was developed by giving the input in Lisrel software. The collected data were verified to acquire analysis results. The standard solutions before and after the index of structural equation model were presented.

As the model proposed in this article meets the index requirements, this model is acceptable. The results show that there is no direct relation between design and execution and applications of information technology, so the acting connection between these parameters is removed. The confirmatory factor analysis among the design and execution and applications of information technology shows a stronger relation, because they closely depend on the same factor of policies and firm coordination. The proposed model obtained by structural equation for supply chain and logistics analysis was presented. The applications of information technology have a significant influence on effectiveness of shipment. However, influences of design and execution on effectiveness of shipment are stronger, while design and execution and applications of information technology are closely related to policies and firm coordination. Though effectiveness of shipment is one of the important indexes for customers and shareholders, excellent logistics performance cannot be separated from high quality design and execution, development and utilization of advanced applications of information technology. All of these should be the concern of the management in supply chain and logistics management. Moreover, it is also necessary to establish a long-term cooperative relationship between consumers and suppliers and provide effective training for workers.

I have reviewed 52 journal articles published over last ten years on the basis of area of application for solving of supplier selection and evaluation problem. The first objective of the review was to find out the most focused area of application in the literature of supplier selection and evaluation. The automobile industry was found to be the most focused followed by manufacturing firm, electronics industry, textile industry, computer manufacturer, refrigerator plant, service company, steel industry, washing machine company, watch firm, fertilizer company, ink cartridge and logistic systems. Most of the authors were found to be interested to develop individual model or integrated model related to supplier selection. Automobile industry contributed 19% of the articles, manufacturing firm contributed 19%, and electronics industry contributed 15% of the research paper while solving supplier selection.

Airplane industry, computer manufacturer, refrigerator plant, service company and steel industry all had contributed only 4% of the articles and remaining area of applications had contributed only 2% of the articles published relating to supplier selection and evaluation problem. De Boer Luitzen stated that supplier related problem is situation specific; it means that the criteria will be different for different area of application that is why it gets more realistic. Supplier selection model proposed by many authors in specific area of application might be applied to another area but not definite that it would be exactly applicable.

The second objective of this review is to find the area of environment. It means that in which situation the author solve the supplier related problem. This was classified it into two major decision criteria, deterministic and uncertainties situation. 33% of papers (17 out of 52) considered uncertainties environment area while 67% of papers (35 out of 52) considered deterministic environment area while solving supplier problem and evaluation. Chai Junyi suggested in his review article that decision environment is defined by uncertainties, decision goal and problem formulation. In studies of decision making, decision environment which does not involve directly or indirectly the uncertainties then it was related to deterministic situations otherwise, it was uncertainties area of environment. Mathematical model is the major decision technique by which the author tackles the deterministic type of decision environment while fuzzy set theory, stochastic programming, and neural network handled the uncertainties situation of supplier problem.

In this 21st century, organizations are confronted with many challenges such as short life cycle of product, short lead time, zero defects, zero accident and so on. To manage these challenges of supply and demand chain a production situation in real life condition was studied.

AHP was used in this article because it draws a relationship between the criteria themselves through pair wise comparisons. Also AHP is the best evaluation index system which is needed to rank the suppliers. However a fuzzy environment prevails in the industry in the selection of supplier. The decision makers compose judgments and an uncertainty can occur. So a fuzzy set is required to give answer for uncertainty.

ANN is another kind in its way such that it has a special learning feature and weights are calculated by assumption. It does not need the help of an expert or a fuzzy integration method. An artificial neural network is an information processing system that has certain performance characteristics in common with biological neural networks. Artificial neural networks were as generalizations of mathematical models of human cognition or neural biology based on some of the assumptions. A neural network is characterized by neurons, method of determining the weights also called training the neuron and its activation function. Each neuron is connected to other neurons by means of direct communication links, each with an associated weight. Each neuron has an internal state called its activation state or activity level which is a function of the inputs it has received.

Decision making process in the tourism sector such as choosing the location from several alternatives of a hotel using past data and applying one or more ANNs to forecast probable future socio-economic data for arriving at the best alternative or choosing the most convenient marketing plan by creating a projection of the future socio-economic data. Also it is used in strategic decision making processes in political, economic and social context. Further, ANN, AHP and fuzzy logic can be utilized to create a supplier selection model separately but their modelling mechanisms and performances are quite different and a comparison is needed to choose the best supplier.

As demand has been uncertain, management was not interested in capital investment for resource acquisition, providing overtime but was interested on outsourcing. A case study was performed in an automobile industry located in outer Chennai of Tamilnadu. The supplier selection model was developed based on five suppliers called S1, S2, S3, S4 and S5 with five evaluating factors, that includes three inputs and two outputs namely Delivery (D) in days, Capacity (Ca) in units, Warranty (W) in number of days, Cost (C) in rupees and Quality (Q) in percentage of acceptance respectively.

Sensitivity analysis is used to determine how the model is “sensitive” during the changes in the value of the parameters of the model and in structure of the model. It is performed to do a trade off study and to check the strength of the model. In sensitivity analysis the values of any one input parameter could be changed and the changes in output performance then measured. In this study equal weights were assumed for the criteria and the efficiency was observed. From the results it was observed that the ranking of the suppliers is not changing and hence the robustness of the proposed model is proved.

Some of the small scale industries were taken for case study for green manufacturing. There were five employees working in the mechanical fabrication industry. One person was doing the marking and gas cutting. Two persons were deployed for drilling, setting and welding. Two persons were working for grinding and painting. Generally all materials were supplied to the industry in the morning. Products were produced and dispatched in the evening of the same day. The factory already follows Just-in-Time. Goods were manufactured based only on the customer order. During the change of product, setting takes more time. A well structured questionnaire was circulated among the local small scale industries of similar type to get ideas for green manufacturing. From the questionnaire survey all the employees' knowledge was gathered and bench marking was done to find the best idea followed by the leading competitor.

As per the suggestions from the employees of various industries the following observations were collected. In the automotive fabrication industry the welding process was advised to be done in a closed chamber with proper exhaust control system instead of in an open area. Similarly in automobile service workshops smoke was to be properly exhausted. A paint booth was recommended to reduce the air pollution. Some of the respondents shared their ideas for using eco friendly points. Also it was suggested for producing electric power on the roofs of the industry by providing 300kw photo voltaic power plants.

Environmental sustainability index was calculated using multi-grade fuzzy approach based on the environmental sustainability evaluation for an automobile manufacturing industry and found it to be 6.1, which signifies that the company follows environmental friendly manufacturing practices and falls within the group of strongly environmental sustainable and acceptable level of 6 to 8. The results very much matched with practical environment, as the company implemented strategies such as 5S, ISO 9001:2008 QMS and ISO 14001 EMS. Some of the areas identified for improving the environmental sustainability of the company were as follows:

1) The company must come up with new technologies to manage sustainable design of green products to augment the eco performance and to minimize wastes occurring in manufacturing stages. Integrated product design applications to be incorporated while designing to deliver an ecofriendly product.
2) Emissions causing air pollution and generation of greenhouse gas to be restricted. The company must strictly adhere to the emission norms and must periodically evaluate the emissions.
3) The usage of non-biodegradable materials and toxic materials exceeding the requirement must be restricted. Eco standard test reports for the materials being used must be maintained and the material should be restricted from usage.
4) The company must allocate cost for adopting proper disposal methods and develop techniques to support remanufacturing. Mass of the disposed consumables must be low and proper disposal method must be followed to dispose them
5) The manufacturing process must support two techniques of recycling and remanufacturing to improve its green performance. The proposed development action helps the manufacturing industry to improve its green performance and also better its ESI.

6.0 Conclusions

These days the main objective of any manufacturing industry is to improve both productivity and effectiveness i.e. customer satisfaction and retention. DCM handles the flow of market based information more frequently and in a detailed structured way than SCM. This necessitates the urgent need to integrate DCM and SCM in order to integrate market information into the planning. One of the most disturbing characteristics of supply chain known as bullwhip effect can be reduced significantly by doing so. The number of organization associated in the supply chain and their relationships are controlled by supply chain standards, the leverage between customer and suppliers, and contracting behavior. Effective manufacturing tools and techniques are to be employed to keep the desired material flow in the chain. Competitive priorities such as performance of distribution centers and management of warehouses could be used as a guide to identify capabilities of demand chain.

Keeping in mind all the above points the studies have been carried out on automotive manufacturing industries based in Chennai, Tamilnadu. The following conclusions were drawn based on the case studies discussed in chapter 4.

1. The mixed-integer linear integrated model was developed with a manufacturer, distributor, retailer, repair site, collection site, disassembly and a recycling site. The developed mixed-integer linear programming model was solved by using IBM ILOG CPLEX optimization studio. To analyze the performance of the developed linear integrated model, numerical examples were used. Through the sensitivity analysis it was observed that, the maximum profit of the CLSC can be attained up to 60% of the products sent to repair site. It was also found that, there were no significant changes beyond 60% of the products. From the observed results it was noted that, as the time period increases profit tend to

decrease due to increased reverse loop costs. The maximum profit can be achieved, if the capacity of disassembly site is kept higher than 600 units.

2. The proposed structural equation model was developed based on the design idea of balanced score card to evaluate the supply chain and logistics performance. The model was designed from the characteristics of design and development, manufacturing point, financial requirement and consumer's point of view. The performance level of supply chain and logistics were evaluated using policies and firm coordination, design and execution, effectiveness of shipment and applications of information technology. Based on the analysis, a supply chain performance evaluation score card with 25 measuring indexes was developed.
3. A large scale industry survey was conducted using the designed score card within India by obtaining 210 effective questionnaires. The reliability and strength of this score card was analysed. From the results it was found that the value of α coefficient was above 0.80, which had indicated that the design of score card for analyzing the supply chain performance was reliable. From the comparative analysis it was found that the performance of supply chains and logistics among the industries, multinational companies exceeded public limited companies and private limited companies in four aspects of the score card, while public limited companies were superior to the private limited companies and small scale industries.
4. Besides, a structural model was developed for the above four aspects and the supply chain and logistics performance was evaluated and the results were obtained. From the results it was concluded that it is essential to establish a long term cooperative relationship among customers and suppliers and provide effective training for workers.
5. A review was carried out on supplier selection and evaluation based on the area of application through a study made from 52 articles published during the

past ten years. Primarily it was exposed that the most focused area to be automobile followed by manufacturing and electronics industry. From this study it was found that around 67% of research articles considered the deterministic environment of area and 33% of articles considered uncertainties environment of area while solving the selection of supplier and evaluation problem. Next it was accepted that uncertainties to be more realistic and accurate decision environment than deterministic.

6. In the earlier research articles, the selection was made by limited categories or criteria. An attempt was made to present the applications of MCDM tools of fuzzy logic and AHP with same example. This case study represented the use of AHP and fuzzy logic in supplier selection with same results. In the case study when AHP were used for a logistics outsourcing problem in tinned foods criteria such as cost, operating efficiency, and service quality and technology level were taken and a pair wise comparison was drawn. The features of fuzzy logic and AHP along with their merits and demerits were also presented in separately.
7. An example on selecting of a car was made using FLDMM whereas in AHP an example of selecting of a best supplier was made using pair wise comparisons and Saaty's scale. In the selection of a car, some criteria such as price, resale value, mileage, comfort and maintenance were taken. Three cars A, B and C were chosen and their price, resale value, mileage, comforts and maintenance data were collected. Also customer's view and perception on price and resale value were considered. In addition the same example of supplier selection was taken using AHP and Fuzzy Logic. Also efforts were made to apply ANN for the selection of supplier. The result gives a suggestion to decision makers in the company in deciding to select a supplier.
8. Decisions of evaluation and selection of a supplier is an important part of supply chain management. In present intense competition, producing high

quality products with minimum cost without satisfaction of suppliers is not possible. From this work based on DEA a multi-criteria decision making model for selection of the best supplier was developed. For which multiple criteria like quality, delivery, cost, capacity and warranty were considered. And the weights of the criteria were computed using FRP technique. The results were compared and finally the robustness of the developed model was also checked by sensitivity analysis. This model gives a reliable result and it can be extended for the same kind of industries. This proposed model can be more flexible to accommodate the qualitative and quantitative criteria for supplier selection. DEA can help to evaluate and compare suppliers in different evaluation criteria which can offer a more robust tool to select and evaluate suppliers based on both the above criteria.

9. The system on green lean infrastructure gives out a channel for the successful implementation of lean green best practices and achievement of corresponding green results. From the survey made it was clearly found that there is tremendous scope for the implementation of the lean green methodologies in small scale industries to save the resources and avoid polluting of the earth. Uniformly suggestions were received from all the industries to produce electric power by using solar panels on the roofs of their industry. By analyzing the impact on environment simultaneously with lean value stream, mapping wastes and pollution could be reduced. The improvement of green lean manufacturing is a continuous process. The incentives to the small scale industries and measures for clean technologies by the government are probably the other way to advance an energetic green wealth.
10. Environmental dimension of sustainability needs main concentration. Sustainability is an essential idea for attaining competitiveness. Environmental sustainability index was calculated for an automobile manufacturing industry using multi-grade fuzzy approach. The ESI of the company was found to be

6.1 and upgrading actions were proposed for further development. Green Manufacturing is an idea for reduction in raw material cost, safety expenses, environmental pollutant and increase in production efficiency. The case study analysis facilitated performance assessment of an environmental sustainability system and subsequent investigation. In order to develop the environmental sustainability of the company, development areas were recognized. On execution of the proposed augmentations, the environmental sustainable performance of the industry could be enhanced.

7.0 Future Scope

Supply chain management and demand chain management being a complex, multi-faceted problem, involves high rate of ambiguity. The models discussed in this thesis are of deterministic type, where blood chemistry plays an important role in the decision making processes. To tackle uncertainties at various stages of supply chain and demand chain procurement, manufacturing and distribution, artificial neural network plays an important role. Market demand is random and uncertain. Recent advancement of information management needs to be exploited fully to meet the demand chain requirement of daily market data collection, compilation and onward transmission. Uncertainty at various stages can be reduced with the help of appropriate information technology tools. Bullwhip effect can be reduced if these uncertainities are arrested.

SCM being precarious and highly sensitive to noises, Concepts of Closed loop supply chain (CLSC) network, Supply chain and logistics management system using balanced score card, Fuzzy logic could be useful in analyzing and understanding the SCM situation better. Fuzzy set theory can be used to measure the fuzzy importance and fuzzy uncertainty importance. Similarly, Lean Green Manufacturing is one of the best way and upcoming practice to bring up small and medium scale industries in improving their performance with regard to environmental conditions. In future a supplier selection in a manufacturing industry for choosing the best supplier ANN, AHP and Fuzzy Logic may be used separately. Various fuzzy applications, such as fuzzy LP and different lean and green manufacturing tools also have a scope for further research in this topic.

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