STUDY OF BARRIERS AND IMPLEMENTATION OF FLEXIBLE MANUFACTURING SYSTEM IN INDIAN AUTOMOBILE INDUSTRY

A DISSERTATION

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IN

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CANDIDATE'S DECLARATION

I, SAJAL GUPTA, Roll No. 2K16/PIE/16 student of M.Tech (Production and Industrial Engineering), hereby declare that the project Dissertation titled "**Study of Barriers and Implementation of Flexible Manufacturing System in Indian Automobile Industry**" which is submitted by me to the Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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I hereby certify that the project Dissertation titled "**Study of Barriers and Implementation of Flexible Manufacturing System in Indian Automobile Industry**" which is submitted by SAJAL GUPTA, Roll No. 2K16/PIE/16 Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Rapidly changing consumer preferences and technological innovation demands enhanced manufacturing flexibility not only for productivity enhancement but for the survival of manufacturing company. Higher manufacturing flexibility offers the company to feed their customers with the variety of product according to their demand. Flexibility in manufacturing system helps to accommodate dynamic changes and helps the company to sustain in the competitive market. This research focuses on prioritization of considered barriers, which are faced during implementation of the Flexible manufacturing system in Indian Automobile Industry. To achieve the objective, a set of significant barriers were identified based on literature review and discussion with field experts, chosen from automobile industry located at National capital region (NCR) of India.

Fuzzy TOPSIS methodology is used to priorities these barriers. Analysis of the findings reveals that top four prioritized factors High initial capital cost, skilled workers, Resource allocation problem, and Floor layout problem are the four most important among all 17 factors. These significant factors to be considered for the effective implementation of flexible manufacturing systems in context to Indian automobile Industry.

Key Words: FMS Barriers, Flexible Manufacturing System, Fuzzy TOPSIS, Fuzzy Logic

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LIST OF ABBREVIATIONS

FMS	Flexible Manufacturing System
ASRS	Automated Storage/Retrieval Systems
CNC	Computer numerically control
AGV	Automated Guided Vehicle
AVGS	Automated Guided Vehicle Systems
GDP	Gross domestic product
MH	Material handling
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TFN	Triangular fuzzy number
MCDM	Multi-criteria decision-making
PIS	Positive ideal solution
NIS	Negative ideal solution
FPIS	Fuzzy positive ideal solution
FNIS	Fuzzy negative ideal solution
FST	Fuzzy Set Theory

CHAPTER 1

INTRODUCTION

1.1 RESEARCH MOTIVATION

The automobile industry is one of the fastest developing sector within the world. In India, it is one of the biggest in the world, with a yearly production of 23.96 million vehicles in FY 2015–16. It accounts for 7.1 per cent of India's gross domestic product (GDP). The Two Wheelers section has an '81' per cent share in the market due to a rapidly growing middle class and a youthful populace. Besides, the increasing intrigued of organizations in exploring the rural markets further backed the development of this sector. Within the Financial year, 2014–15, trades in vehicle segment expanded by 15 per cent in comparison to the former year. Moreover, a few efforts by the government and the influential professionals will push forward to become a pioneer in the automobile sector.

India is also a leading automotive goods exporter and expected to have a strong export growth in the coming future. With increase in demand, customer preference for product variety and technological improvements to attain smaller lead-times with higher productivity and quality, there is the need for automobile company to accommodate these changes as quickly as possible to sustain in the competitive market. Flexible Manufacturing System (FMS) can respond to market fluctuations rapidly and at less cost.

To accommodate this growth and to sustain in the competitive market, there is a need for the automobile company to adopt flexible manufacturing system. Flexibility in automobile industry helps the company to adopt technological innovations and deliver goods in huge varieties to fulfil the requirement of the customers.

A Flexible Manufacturing System (FMS) is operated by the central control system which comprises of a set of processing workstations (commonly CNC machine tools) interconnected by an 'automated material handling system' having the capability of Automated Storage/Retrieval Systems (ASRS)

Flexible manufacturing systems (FMS) are beneficial in following ways:

- They retain high productivity by decreasing lead time and wastage.
- Fulfil customers need by providing the wide variety of products.
- Reduces overall manufacturing Costs.
- Keeps low production labor costs and Increases total company revenues.

The optimal designing of FMS is an important issue, and it is a complicated problem. There are several barriers that affect the implementation of flexible manufacturing system in context to Indian automobile industry. These barriers are identified as faces various barriers such as Technical barriers, Operational barriers, financial barriers and Strategic barriers.

The objective of this research is to identify various barrier which an automobile company faces during the implementation of FMS and prioritize them using Fuzzy TOPSIS methodology.

1.2 FLEXIBLE MANUFACTURING SYSTEM

A Flexible Manufacturing System (FMS) is operated by the central control system which is comprises of a set of processing workstations (usually CNC machine tools) interconnected by an 'automated material handling system' having the capability of Automated Storage/Retrieval Systems (ASRS).

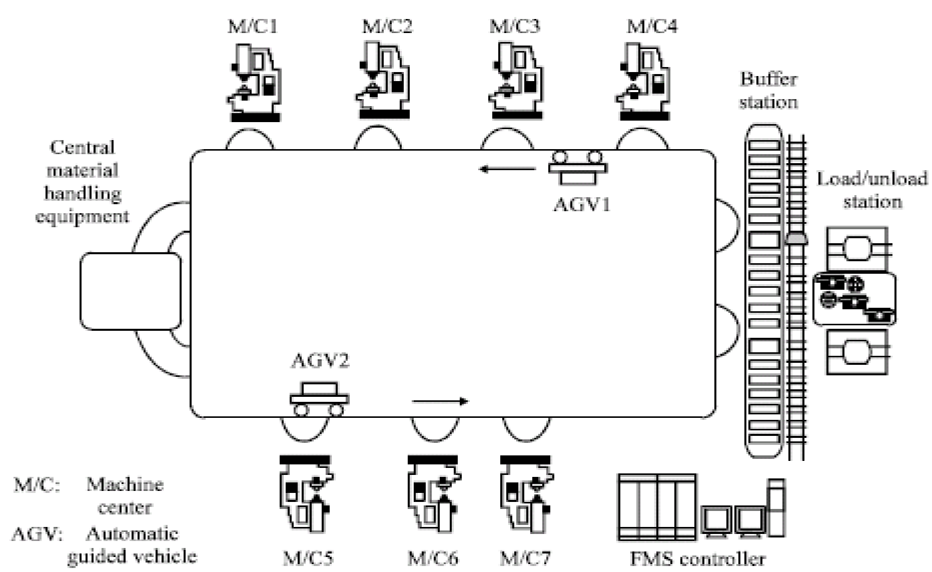

Fig. 1.1 Schematic representation of an FMS environment (Buzacott and Yao, 1986)

1.3 ADVANTAGES OF FLEXIBLE MANUFACTURING SYSTEM

- Increases Productivity: 'FMSs' are more efficient than conventional manufacturing systems, and there is little space for time waste and material waste.
- Customer Satisfaction: 'FMS's are capable of meeting customer demand for high product variety with smaller lead time.
- Decreases Manufacturing Cost: It helps in reducing the cost of product per unit.
- Increases Revenues: Flexible manufacturing system (FMS) can react to market changes rapidly, and at less expense, thus the company can capitalize on market changes
- FMS helps in keeping production labor Costs Down and Productivity Up: Cross-training fulltime staff for slow seasons and using part-timers or contract employees only for busy seasons.
- Working with CAD/CAM: FMS helps in enabling synergy with these technologies.

1.4 BASIC COMPONENT OF FMS

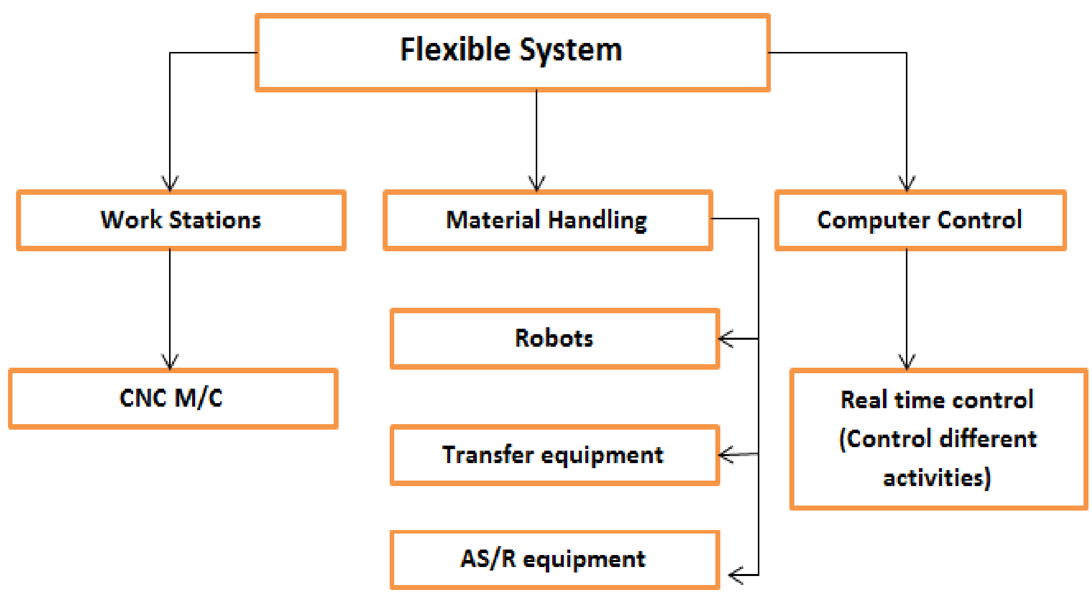

Fig 1.2 Basic Components of FMS

The basic components of FMS are:

A) Workstations

B) Automated Material Handling and Storage system

C) Computer Control System

1.4.1 Workstations

In FMS, workstations are computer numerically control (CNC) machine tools that deliver all the needed machining operation on the part families. "Flexible manufacturing systems are designed with another type of processing equipment including inspection stations, assembly works and sheet metal presses. Different workstations are presented below:

- Centers of Machining,
- Stations for Loading and Unloading,
- Workstation for assembly,
- Stations for Inspection,
- Stations for Forge,
- Process to sheet metals, etc.

1.4.2 Automated Material Transporting and Storage system

Different automated material transporting systems are employed for transportation of work parts and subassembly parts between the workstations, sometimes incorporating storage into the function. The various functions of automated material handling and storage system are as follows:

- Work part's independent and random movement between different workstations
- Ability to handle the several types of work part configurations.
- Storage of work parts for a short period.
- Convenient access for unloading and loading of work parts
- Compatible with computer control system.

1.4.3 Computer Control System

They are used for coordinating the various activities of material handling operation and processing stations in the FMS. The multiple functions of the computer controlling system are:

- Controlling of each workstation
- Delivery of control instruction to the workstation
- Controlling Production
- Controlling of Traffic Vs controlling of Shuttle
- Job monitoring and handling system
- Monitoring of System performance

1.5 FLEXIBILITY AND ITS TYPES

The various types of flexibility that are held by flexible manufacturing systems are as follow:

1.5.1 Machine Flexibility

Machine Flexibility: Capability to adopt a provided machine in the system to a broad variety of production processes and part styles is known as Machine flexibility. The broader the range of processes and part styles the larger will be the machine flexibility. There are several factors over which the flexibility of machine in a system depends upon, are as follows:

- Setup or change over time
- The ease with which part-programs can be loaded to machines
- Tool storage capability of machines
- Experience and versatility of operators in the systems

1.5.2 Production Flexibility

It can be described as the ability to produce the variety of part styles within the system. The process envelope determines the range of 'part styles' that can be manufactured by a production system at reasonable cost and in optimum time. Following factors over which production depends are as follows:

- Machine flexibility of each workstation
- The Range of machine flexibilities of every station

1.5.3 Mix Flexibility

It is defined as the ability to adjust the product mix while maintaining the same cumulative production quantity that is, producing the same parts only varying in amount. It is also known as process flexibility. Mix flexibility gives security against variation in the market by accommodating variations in product mix by using shared resources. However, large mix variations results in higher demand of fixtures, tools, and other necessary resources.

Factors upon which mixed flexibility relies are as follows:

- The similarity of parts/component in mix
- Machine flexibility
- Relative work content times of parts produced

1.5.4 Product Flexibility

It is defined as the ability to adopt a fresh set of products quickly and economically in response to the dynamic market requirements.

The change over time comprises of time required for design, preparation, fixturing and tooling of new products proposed in the production line-up. Factors over which it depend are as follows:

- The similarity of fresh part design with the existing part family
- Off-line part program preparation
- Machine flexibility

1.5.5 Routing Flexibility

It can described as the capability to process parts on another working station in case of failure of machines, damage to tools, and other obstacles at any particular station. It assists in improving throughput, in the case of outdoor changes such as product mix, engineering modifications, or new product introduction. The factors over which routing flexibility depends are as follows:

- Relatedness of parts in the mix
- Common tooling

1.5.6 Volume Flexibility

It can be described as the capacity of the system to shift production quantities of different product to accommodate variations in demand while continuing profitable. It can also be called as capacity flexibility. Factors over which volume flexibility depends are as follows:

- Level of hand-operated labor performing production.
- Amount spent on capital equipment.

1.5.7 Expansion Flexibility

It is described as the ease through which the system can be modified to increase overall production quantity. Factors over which expansion flexibility depends are as follows:

- Amount of investment required in adding additional workstations and skilled workers.
- Ease of expansion of layout.

1.6 PROBLEM STATEMENT AND OBJECTIVE

Rapidly changing consumer preferences and technological innovation demands enhanced manufacturing flexibility not only for productivity enhancement but for the survival of manufacturing company. The higher manufacturing flexibility offers the company to feed their customers with the variety of product according to their demand. Flexibility in manufacturing system helps to accommodate dynamic changes and helps the company to sustain in the competitive market. This research focuses on prioritization of the considered barriers, which are faced during implementation of the Flexible manufacturing system in Indian Automobile Industry.

The objective of the present project work is to identify various barrier which an automobile company faces during the implementation of FMS and prioritize them using Fuzzy TOPSIS methodology.

1.7 ORGANIZATION OF THESIS

This thesis is being organized into six chapters as summarized below:-

- Chapter 1 covers the introduction of flexible manufacturing system, its basic components, and types of flexibility. It focus on the need for implementation of flexible manufacturing system in Indian automobile industry.
- Chapter 2 includes the literature survey on implementation of FMS .It focuses on implementation procedure and various issues which are faced during implementation of FMS.
- Chapter 3 covers the various steps to be followed in this research work. It includes identification of barriers faced during FMS implementation, questionnaire development, data collection and deployment of Fuzzy TOPSIS methodology.
- Chapter 4 covers methodology used in this research work for prioritization of identified barriers faced during the implementation of flexible manufacturing system. It includes fuzzy logic introduction and then methodologies TOPSIS, Fuzzy TOPSIS. Firstly fuzzy logic is discussed, and then TOPSIS and Fuzzy TOPSIS are discussed.
- In Chapter 5, a case study for implementation of flexible manufacturing system in Indian Automobile Industry is presented. The Fuzzy TOPSIS methodology is used for the ranking of barriers which company face during implementation of FMS so that company may reduce lead time and increase profit.
- Chapter 6 includes conclusion and future scope for this research work.

CHAPTER 2
LITERATURE REVIEW

Continuously increasing customer requirements and changing needs, improved manufacturing methods, new technologies and government regulations, the shortening lifecycle of the individual products requires manufacturing industries need to continuously upgrade their products, processes and technologies to remain competitive **(**Lafou et al 2016**).**

Chryssolouris et al (2013) defined flexibility as “the sensitivity of a manufacturing system to changes”. The more flexible a system, the less sensitive to changes occurring to its environment it is.The ability of modern factories to be flexible, efficient and appropriately responding to unpredictable changes in market requests represent a key factor to boost their competitiveness in the global market, allowing quick reactions to variable market demands and the delivery of highly customized products **(**Bhosale et al**.** 2018). Thus there is a need for manufacturing industry to adopt flexible manufacturing system to accommodate dynamic changes and to sustain in the competitive market. Flexible manufacturing systems are modern production facilities that are adaptable to different production plans.

FMS is integrating hardware and software elements and is defined as ‘a collection of production equipment logically organized under a host computer and physically connected by a central transport system **(**Lafou et al 2016**).** The hardware elements are made up of computer numerically controlled (CNC) machines equipped with tool magazine, pallet, loading and unloading station, buffer for processing parts, material transport and handling equipment such as automated guide vehicle (AGV) and conveyor. The automotive industry is one of the fastest growing sectors in the world. In India, it is one of the largest in the world with an annual production of 23.96 million vehicles in 2015–16. It accounts for 7.1 percent of India's gross domestic product (GDP). The Two Wheelers segment has 81 percent market share due to a growing middle class and a young population. Moreover, the increasing interest of companies in exploring the rural markets further supported the growth of this sector.

India is also a leading auto exporter and has strong export growth expectations for the near future. In FY 2014–15, automobile exports grew by 15 percent over the last year. Also, several actions by the Government and the major automobile players in the Indian market are expected to make India a leader in the Two Wheeler and Four Wheeler market in the world by 2020.

2.1 IMPLEMENTATION PROCEDURE FOR FMS

Several authors have presented articles, which describe various steps necessary for the implementation of FMS technology. Fry and Smith (1989) have described a detailed procedure for the implementation of FMS in Department of Defense of U.S. They have proposed the following eight distinct stages in the implementation of a flexible manufacturing system, i.e., (i) identify the manufacturing requirements of the parts to be produced, (ii) identify and evaluate the alternative technologies, (iii) choose the appropriate technology, (iv) send out requests for proposals, (v) evaluate and select the vendor, (vi) installation of FMS, (vii) system configuration, and (viii) shake down the system. Primrose and Leonard (1991) have suggested that the implementation procedure for flexible technology can be divided into three steps, i.e., (i) investment appraisal, (ii) technology selection and (iii) technical installation.

Groover (2003) has also discussed FMS planning and implementation issue. He has proposed that this issue should be divided in two phases, i.e., (i) FMS planning and design phase and (ii) FMS operational phase. For the first phase, he has proposed the consideration of part family, processing requirements, physical characteristics of the work parts, production volume, types of workstations, variations in process routings and FMS layout, material handling system, work-in-process inventory, cutting tools and pallet fixtures. For handling the second phase, he has proposed that operational problems must be solved through proper scheduling and dispatching, machine loading, part routing, part grouping, tool management and pallet and fixture allocation. Rezaie and Ostadi (2007) have introduced a dynamic programming model to analyze the optimal and phased implementation of flexible technology in a manufacturing system.

2.2 RESEARCH RELATED TO FMS IMPLEMENTATION

From the study of other articles on the same issue, it is found that no clear-cut procedure for the implementation of FMS has been proposed. Instead, many complex techniques like expert systems, artificial intelligence and neural network, etc., have been experimented and suggested for the implementation and integration of different components of FMS, which are so complex that it is often infeasible to apply them in the real-life implementation of FMS. The existing research work is found to be handicapped in fully answering the following questions, which are generally asked by the manufacturing managers in the industry for a possible transition of their traditional manufacturing system to FMS:

- What types of technologies, standard industrial networks and protocols are available for FMS system integration and how are they managed?
- What types of software, sensors and other mechatronic components are available for the system integration? What are their related constraints and how are they managed in realistic situations?
- How will the unmanned operations of FMS be managed, especially in a third shift? How will the problems related to tool management and maintenance be looked after in the third shift?
- How quickly can one shift to FMS? If a typical traditional company wants to adopt FMS, then, how much time is needed for its transition?
- How much gain in profits (i.e., economical efficiency), flexibility, automation and productivity, etc., can be expected over the time horizon? If a decision for FMS installation is taken, then (i) how much time is needed to achieve the breakeven, (ii) when will the profits start pouring in, and (iii) how will the new production system be successful in a long run?
- How much flexibility will be achieved? If a new random part is to be manufactured in FMS on an urgent basis and a sudden design change is required in the product configuration according to market demand, then, how quickly can it be handled in the FMS?

- How will pallets and fixtures handle a variety of parts? Groover (2003) has suggested the use of a number of fixtures for different parts. No doubt, different pallets and fixtures can be utilized and procured for a number of parts, but (i) how much setting time will be required for different pallets and fixtures, (ii) for how much time will the system be idle, (iii) how many parts can a single pallet or fixture handle, (iv) if somehow flexible fixtures are designed, then what about their cost and complexity, (v) if flexible fixtures are not available then, what will be the difference between an FMS and a simple automated production system, and (vi) where is the flexibility in the system in such a case?
- Generally, there is a scarcity of vendors supplying all the components of FMS, i.e., there are different manufacturers of computer numerical control (CNC) machines, robots, automatic guided vehicles (AGVs), co-ordinate measuring machines (CMMs), conveyors, automatic storage and retrieval system (AS/RS), etc. In developing countries, there is even scarcity of manufacturers of robots and AGVs. When these hardware components are purchased from different vendors, then what is the best way for the integration of these components?
- What about system maintenance and its up-gradation in a long run?
- What about training and upgrading the skills of engineers and concerned staff in the area of FMS in a country where these systems have not been introduced?

We believe that these questions are really irritating and these have not been properly addressed by the researchers. A dedicated research work is still pending for finding the solution to the real-life problems related to planning and implementation of FMS.

2.3 ISSUES FACED DURING IMPLEMENTATION OF FMS

Adaptation of flexible manufacturing system is a complicated process. Raj et al. (2008) provided a brief view of various barriers which were faced in implementation of FMS in any manufacturing industry. Implementation of FMS faces various issues which are given below:

2.3.1 Issue regarding Skilled labor in FMS

FMS involves various complex operation that includes programming of machines, the pre-setting of tools, monitoring, job setting, maintenance, repairs, and manipulations of the system control. These complex operations required skilled workforce who can perform these operations. But there lack of skilled labors and is the one of the critical issue which faced during implementation of Flexible manufacturing system. Moreover the various demands of the skilled worker like higher incentives, less working hours, also impact in successful implementation of FMS (Slack, 1987).

2.3.2 Issue regarding tool management decisions in FMS

Tool management can be defined as getting the right tool, to the right place at the right time and it seems to be one of the most cumbersome and difficult issues to deal with. Sharit et al. (1989) suggested that the need for tool management arises from the high variety and number of cutting tools that are typically found in automated manufacturing systems. The tool-related activities account for about 25–30% of the on-going operating costs of FMS, significant costs can be avoided by appropriate tool management strategies. The adoption of appropriate tool management policies that consider alternative cutting tools allows the desired part mix and quantities to be manufactured efficiently while achieving improved system performance**.**

2.3.3 Issue regarding machine loading

The FMS loading problem is to allocate operations and associated tooling of a selected set of part types among the machine groups, according to some appropriate (system dependent) loading objective, also subject to technological and capacity constraints (Lee et al. 1993) . Stecke et al. (1981) studied machine loading problems in detail and described its six main objectives**:**

- Balancing the machine processing time.
- Minimizing the number of movements.
- Balancing the workload per machine for a system of groups of pooled machines of equal sizes.

- Unbalancing the workload per machine for a system of groups of pooled machines of unequal sizes.
- Filling the tool magazines as densely as possible.
- Maximizing the sum of operations priorities.

2.3.4 Issue regarding scheduling in FMS

An FMS scheduling problem is considered to be a detailed minute-by-minute scheduling of the machines, materials handling system, and other support equipment **(**Kumar et al. 2006**).**

Given the actual shop conditions and a set of parts with known processing requirements, it is concerned with accomplishing the following tasks:

- Schedule actual job release times.
- Sequence the jobs and determine the start and completion times of each operation on a wide variety of resources.
- Monitor the execution of the schedule and provide effective contingency handling.

2.3.5 Issue regarding floor layout in FMS

Yang et al**. (**2005) proposed that the poor layout and flow path design can result in high material handling costs, excessive work-in-process inventories, and low or unbalanced equipment utilization. To obtain high productivity, efficient layout arrangement and material flow path design are critical due to the high percentage of product cost that is related to material handling. Ficko et al (2004) suggested genetic algorithms methods for layout designing.

2.3.6 Issue regarding poor efficiencies of equipment

De Carvalho et al. (2015) evaluated that in the industry, the cost of electricity, although increasing, is not regarded as a production cost, and thus the energy efficiencies of equipment are usually not considered To gain knowledge about energy efficiencies in the machining industry, this study proposes a new method of evaluating the machining process and the machines, devices, and equipment involved.

2.3.7 Issue regarding machine grouping

Partition the machine tools of each machine type into machine groups such that each machine in a particular group is able to perform the same set of operations. The FMS machine grouping problem is to partition the m i machine tools of type i into g, groups to maximize expected production, subject to FMS technological and capacity constraints. Machines in a group are identically tooled and hence can perform the same operations during production (Stecke et al**.** 1986**).**

2.3.8 Issue regarding deadlock condition

Lei et al. 2014 described deadlock is an extremely undesirable state in which each of a set of two or more work piece continues to wait endlessly for the other work piece in the set to free resources. In deadlock situations, the whole system or a part of it remains indefinitely blocked and cannot terminate its task. Therefore, it is highly important to develop efficient control and scheduling algorithms to optimize the system performance while preventing deadlock situations.

2.3.9 Issue regarding capacity allocation

The operation assignment and capacity allocation problem in FMSs can be stated as follows: given a set of operations each belonging to a specific part type, assign the operations and tools to the capacitated CNC machines. The problem may have several objectives such as maximizing the total weight of the assigned operations, minimizing the total tool usage cost, maximizing the utilization of the machines (Özpeynirci et al**.** 2009**)**

2.3.10 Issue regarding collisions in automatic guide vehicle

An Automated Guided Vehicle System (AGVS) is a material handling system that uses independently operated, self-propelled vehicles guided along defined pathways in the facility floor. It is an automated material handling system which moves along predefined and preprogrammed path along an aisle from one station to another. The main parts of an AGV include structure, drive system, steering mechanism, power source (battery) and onboard computer for control. Automated guided vehicles (AGVs) are known for their routing flexibility advantage. Despite of this advantage, AGVs have the disadvantage of being more difficult to control. Many issues need to be resolved in AGV control, one of which is vehicle collision prevention (Liao et al.2009).

Maxwell and Muckstadt (1982) studied the problem of the design of an AGV system. They did pioneering work in analytical modeling of operational features of an AGV system. In an environment comprising primarily of assembly operations for finished products, they proposed a time-independent model to estimate the minimum number of vehicles required to support the material handling needs.

2.3.11 Issue regarding initial capital required in FMS

FMS encourages technological change and innovation. However, such a system also requires extensive capital expenditure, which is a discouraging factor in adopting FMS. This implies that it is necessary to carefully analyze the costs against the benefits of FMS in order to make proper decisions (Shang et al. 1995).

The cost of FMS is the investment needed to ensure the operation of the system. It comprises the cost of acquiring and operating the production facility. Three categories of cost can be identified. They are

- Equipment acquisition (machine tool and material handling, installation and training, fixture and jigs, programming, computers and communication cost).
- Operating (labor, maintenance, energy, material and management cost, information tracking cost).
- Floor space requirement.

2.3.12 Issue regarding selection of material handling system

Material handling can be defined as an integrated system involving activities such as moving, handling, storing and controlling of materials by means of gravity, manually or with machinery. Singh et al. (2016) suggested that material handling is an important area of concern in flexible manufacturing systems because more than 80% of time that material spends on a shop floor is spent either in waiting or in transportation, although both these activities are non-value added activities. Efficient material handling is needed for less congestion, timely delivery and reduced idle time of machines due to no availability or accumulation of materials at workstations. Safe handling of materials is important in a plant as it reduces wastage; breakage, loss and rejection etc**.**

2.3.13 Issue regarding excessive Tool switching

Konak et al**. (**2008) studied that, in cases where the total number of tool slots required by all part types is larger than the tool magazine capacity, tool loadings or switching between the processing of the part types become inevitable. Tool loading or switching usually consumes time and therefore may delay the planned production. Even though the tool magazine capacities of the CNC machines have increased by the advances in new technologies, the tool types required to process part types have also increased due to the advances in the part complexity. Kouvelis (1991) described a two-level hierarchical scheme for determining optimal number of tools of each type required for efficient operation of manufacturing system over a planning horizon on minimum cost basis. At the first level, a long-term operations assignment to machines is specified and at the second level, the optimal tooling decision is made.

2.3.14 Issue regarding part type Selection Problem

Part type selection which determines a subset from the set of part types having production requirements for immediate and simultaneous processing. When several jobs (part types) arrive, the System must select which part types should be taken into production batch produced immediately while satisfy several technological constraints such as machines scheduling period, tool and tool type availability **(**Srivastava et al. 1996**).**

2.3.15 Issue regarding resource allocation

Resources of an FMS can be workstations, work cells, machines, robots, transportation devices, computers, sensors, tools, fixtures, buffers, and parts. Each of these resources has certain attributes in terms of capabilities and can satisfy the needs of tasks and of other resource.

2.3.16 Issue regarding routing mix of product

The FMS routing mix problem is to determine which of the feasible routes of each part through the manufacturing system should be chosen and also the number of units of a particular product to be produced along the chosen routes. The term route of a part through the manufacturing system usually means a sequence of workstations the part has to visit in order to complete its processing requirements. Qin et al. (2016) described routing mix problem is very important since it impacts the routing flexibility of a FMS, a feature with tremendous importance for efficient real time scheduling of the automated System**.**

2.3.17 Issue regarding government Policies

Jain et al. (2008) suggested that government policy towards manufacturing industries is one of the key factors that facilitate the adoption of FMS. The government provides land and power facilities at reduced rates in certain areas to develop new industrial parks. Taxes are also low in such areas. So these opportunities should be available to organizations which have financial problems.

CHAPTER 3

RESEARCH METHODOLOGY

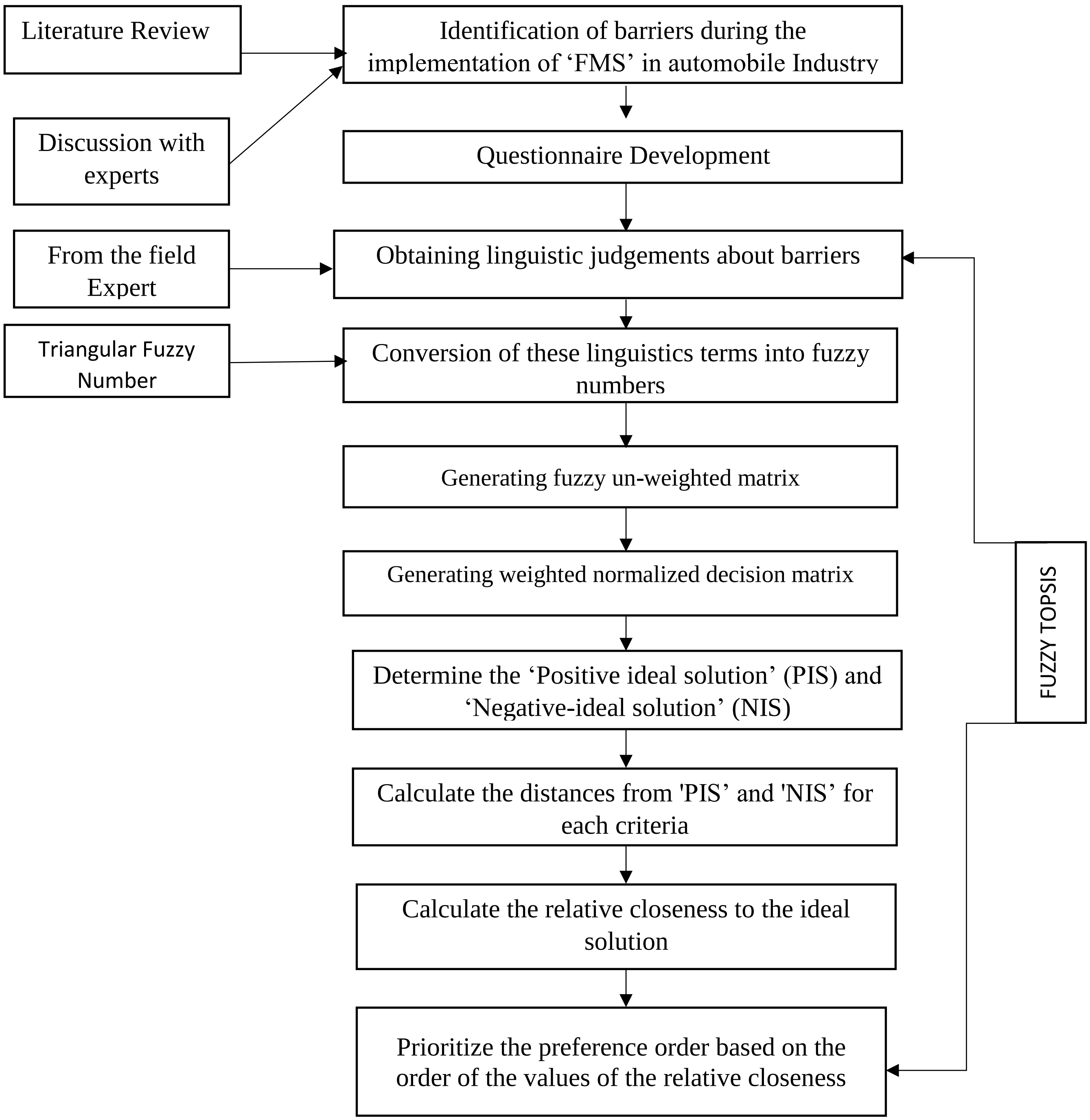

Fig 3.1 Flow Chart of Work

3.1 INTRODUCTION

The objective of this research is to evaluate the importance level of considered barriers faced in implementation of the Flexible manufacturing system in Indian Automobile Industry. To achieve the objective, a set of significant barriers were identified based on literature review and discussion with field experts, chosen from automobile industry located at National capital region (NCR) of India. For the discussion purpose, extensive brainstorming sessions (with industrial and academic experts) were fixed to strengthen and improve the literature inputs. A questionnaire has been formulated on five-point scale (1 for Low importance…..5 for highest importance) and send to the field experts to collect their opinions in order to know the most significant barrier among them.

3.2 IDENTIFICATION OF BARRIERS

Table 3.1 List of Identified Barriers

S NO.	BARRIERS	EXPLANATION	AUTHORS
`1	Requirement of Skilled Labor	FMS involves complex operation that includes programming of machines, the pre-setting of tools, monitoring, job setting, maintenance, repairs, and manipulations of the system control, which requires skilled labor.	Slack, (1987),
2	Tool management decisions	Tool management requirement comes from the vast variety and the massive number of cutting tools that are found in automated production systems. The tool-relevant activities accounted for about 24–30% of the operating costs of FMS.	Konak et al. (2008) , Buyurgan et al. (2004)

3	Machine loading problem	The FMS loading problem deals with the allocation of work to the various machine, and associated tooling of a selected set of part types among the different machine groups to meet particular performance measures.	Gamila et al. (2003), Bottani et al. (2017)
4	Complexity in Scheduling	Scheduling problem include determining the optimal input sequence of parts and an optimal sequence at each machine tool given the current part mix	Gang et al (2016), Sabuncuoglu et al. (1992)
5	Floor layout problem	Floor layout problem is determining relative locations and the allocation of provided space among various workstations. A poor floor layout and flow path designing lead to higher material handling expenses, high work-in-process inventory, and less or unbalanced machine utilization. The problem of obtaining an optimal or near optimal layout for an FMS is one of the problems	Ficko et al (2010), yang et al.(2005)
6	Poor efficiencies of equipment	The decrease in the efficiency of the equipment cause rise in production cost.	de Carvalho et al. (2015), de Oliveira Gomes et al. (2015)

7.	Machine grouping	'Machine grouping problem' is to divide the machine tools of similar type into groups such that machine in a given group can implement the same set of required operations. The foremost purpose is to maximize overall production.	Stecke et al. (1986), Kumar et al. (1986)
8.	Deadlock	A deadlock is an extremely undesirable state in which each of a set of two or more work piece continues to wait endlessly for the other work piece in the set to free resources.	Lei et al. (2014), Zhou et al. (2004)
9.	Capacity allocation problem	The Capacity allocation problem may have numerous objectives such as maximizing the total weight of the assigned operations, minimizing the total tool usage cost, maximizing the usage of the given machines.	Özpeynirci et al. (2009), Bilgin et al. (2006)
10.	Collisions in automatic guide vehicle	Automated Guided Vehicle Systems (AGVSs) are superior material-handling devices employed for transporting pieces among the various workstations, face some traffic problem like collision.	Liao et al. (2009), Hsueh et al. (2010), Lee et al. (1995), Shirazi et al. (2010)

11.	High initial capital cost	FMS promotes technological advancement and innovation. Therefore such system requires enormous capital investment, which is a discouraging factor in adopting.	Al-Kahtani et al. (2014), Nelson et al. (2015)
12.	Selection of material handling system	Proper material handling is required for lower congestion, timely transportation and reducing machine's idle time due to no availability or collection of materials at workstations.	Singh et al. (2015)
13.	Excessive Tool Switching	Tool loading or switching usually consumes time and therefore may delay the planned production.	Konak et al.(2008), Shirazi et al. (2001)
14.	Part type selection problem	This problem defines the part types to be produced in the FMS out of the overall production demand of the company.	Kusiak (1985)
15.	Resource allocation problem	Resource allocation in an FMS is the allotment of resources to tasks. Resources of an FMS can be workstations, work cells, machines, robots, transportation devices, computers, sensors, tools, fixtures, buffers, and parts.	Kusiak (1985), Shen (1991)

16.	Routing mix problem	The aim of FMS routing mix problem is to choose the feasible routes for the particular part through the production system and also to determine the number of units of a specific product to be manufactured along the chosen routes.	Qin et al. (2016), Avonts et al. (1988)
17.	Government Policies	Government policy towards manufacturing industries is one of the critical factors that facilitate the adoption of FMS. The government provides land and power facilities at reduced rates in certain areas to develop new industrial parks.	Vokurka et al. (2000)

3.3 QUESTIONNAIRE DEVELOPMENT

Based on the identification of barriers in the table 3.1 and discussion with the field expert, a questionnaire will be developed. For the ease of collecting data questionnaire is built in the form of Google Docs**.**

3.4 DATA COLLECTION AND ANALYSIS

After the development of the questionnaire, it will be send to industries for opinion survey from the employee working in manufacturing system. All mailings included a cover letter and a questionnaire. Date collected from surveys will be used for further analysis.

3.5 DEPLOYMENT OF FUZZY TOPSIS METHODOLOGY

Fuzzy TOPSIS Methodology has been used for ranking the various barriers to finding the most significant barrier among them.

CHAPTER 4

FUZZY TOPSIS METHODOLOGY

4.1 INTRODUCTION

This chapter contains methodology used in this thesis for evaluating and ranking of various barriers faced in implementation of flexible manufacturing system. The chapter consists of fuzzy logic introduction and then methodologies TOPSIS, Fuzzy TOPSIS. Firstly fuzzy logic is discussed, and then TOPSIS and Fuzzy TOPSIS are discussed. Fuzzy TOPSIS is used for evaluating and ranking of various barriers.

4.2 FUZZY LOGIC

Fuzzy logic is a kind of 'multi-valued logic' which was derived from the theory of fuzzy set to deal with the logic that is estimated rather than exact. Most practical decision difficulties take place in a complicated environment where given information is imprecise and uncertain information, complex systems of logic and probably uncertain preferences have to be analysed. To face such complexity, the use of specific tools, techniques, and concepts which allow the available information or data to be represented with the appropriate granularity is considered as important. Particularly, the fuzzy set theory is generally used to tackle with this type of problems (Nădăban et al. 2016). Ali et al. (2016) derived a fuzzy logic model for long-duration load prediction. For this, a fuzzy logic model is generated which is based on the parameters of weather, i.e. .humidity, temperature and old load data for Mubi town in the state of Adamawa to predict a year-before load. The fuzzy logic model predicted a year-before load with a MAPE of 6.9 per cent and efficiency of 93.1 per cent. The result got revealed that the suggested model is able in forecasting future load.

Biezma et al. **(**2018) used a Fuzzy Logic method for foretelling the rate of external surface corrosion on the bases of the combination of the analysis of 6 soil parameters, and a decreased value of inspection corrosion rate data is presented. The method provides a comparatively user-friendly procedure that can be adopted by the industry to concentrate the efforts towards optimizing the protection and the continuity of the service**.**

Tomer et al. (2018) use a combination of logistic regression with fuzzy logic to resolve traffic congestion. It is used to calculate the probability of every possible path by considering the real-time traffic information, distance and road condition and later is used to take decisions in a vague scenario. The Proposed method considers the number of parameters like distance, weather condition, road location, the day of week and time.

Barlybayev et al. (2016) introduce a fuzzy model for evaluating the performance of students by the establishment of performance. The purpose of this method is a qualitative measurement of the capability of students, without the use of equations for the estimation of student performance. It helps in the straightforward calculation of the average amount of progress for each student.

Zehtabch et al. (2018) revealed the fuzzy logic model to foretell the compressive strength of the asphalt specimens in different situations including varying optimum bitumen percentage, adding granular polymer modified 'bitumen', and using varying portions of 'fractured particles'. The results were matched with laboratory measurements to conclude the correctness of the fuzzy logic model.

4.3 FUZZY SET THEORY

The fuzzy set theory proposed by Zadeh (1965) is used for representing ambiguity in human thought; it extends conventional logic to include instances of partial truth. In traditional set theory, elements have either full membership or null-membership in a provided set. Fuzzy set theory permitted the intermediate level of membership. The coding of the level of membership for each of the elements in the given set is defined as the fuzzy set membership function. The membership function is commonly depicted as a membership curve. The membership curve contains three main components: the horizontal axis consisting of domain elements (usually real numbers) of the fuzzy set, the vertical axis consisting of the level of membership scale from 0 to1, and the surface of the set itself which relates the level of membership to the domain element.

These membership curves may have numerous shapes, but the trapezoidal and triangular are the most generally used. This type of methodology is beneficial when the model needs human perceptions as inputs where ambiguity and vagueness exists. In particular, systems requiring linguistic descriptions are more easily modelled using fuzzy sets. There are two primary inputs to the evaluation process of data. The first is the decision maker's perception regarding the importance weight of the criteria of interest. The second input is how the decision-maker rates each parameter with respect to an objective. However, it is very challenging to obtain precise assessments from the decision maker. Assessments are generally subjective and qualitative and thus forcing the decision makers to state their opinion in pure numeric scales, do not permit any scope for subjectivity. Subjectivity of human evaluations and beliefs can be expressed by utilizing linguistic terms such as "low importance" or "highly likely." The fuzzy set theory and fuzzy numbers permit such qualitative expressions. As a result, their use in modelling of our proposed system seems a logical choice.

4.4 FUZZY NUMBERS

Fuzzy numbers are the specific classes of fuzzy quantities. A fuzzy number is a fuzzy quantity N that depicts a generalization of a real number 'r' intuitively; N(x) should be a measure of how well N (x) "approximates" 'r'. A fuzzy number N is a convex normalized fuzzy set. A fuzzy number is characterized by a given interval of real numbers, each with a grade of membership between 0 and 1. A triangular fuzzy number (TFN), N is shown in Figure 4.1.

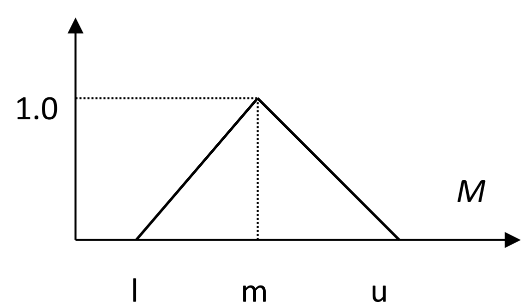

Fig 4.1: Triangular Fuzzy Number

4.4.1 Triangular Fuzzy Number

Triangular fuzzy numbers are expressed by three real numbers, expressed as (l, m, n) The parameters 'l' , 'm' and 'n' respectively, indicate the least permissible value, the most promising value, and the highest permissible value that represent a fuzzy event. The membership functions are expressed as:

$$\mu(x / \tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \leq x \leq m, \\ (u-x)/(u-m), & m \leq x \leq u, \\ 0, & x > u \end{cases}$$

In application, working with TFNs is very convenient because of their simplicity in computational, as well as they are helpful in improving representation and data evaluation in a fuzzy situation or when the given date is not precise. In this study TFNs in the Fuzzy TOPSIS is adopted.

4.4.2 Algebraic operation on TFNs

The majority of us know about arithmetical processes with crisp numbers, but when we need to use fuzzy sets in applications, we have to understand fuzzy numbers. We can define various operations on TFNs. But in this section, important operations used in this study are illustrated. If we represent, two TFNs 'A' and 'B' with the triplets A= (l_a, m_a, u_a) and B=(l_a, m_b, u_b). Then

Multiplication:

$$A.B = (l_a, m_a, u_a).(l_b, m_b, u_b)$$

$$= (l_a l_b, m_a m_b, u_a u_b)$$

Inverse:

$$(l_a, m_a, u_a)^{-1} = (\frac{1}{u_a}, \frac{1}{m_a}, \frac{1}{l_a})$$

Distance between Two triangular Fuzzy numbers:

Distance between two 'triangular fuzzy numbers' 'a'=(l_a, m_a, u_a) and 'b'=(l_b, m_b, u_b) can be calculated as follows:

$$d(a,b) = \sqrt{\frac{1}{3}[(l_a - l_b)^2 + (m_a - m_b)^2 + (u_a - u_b)^2]}$$

$$d(a,b) \in R^+$$

Distance between two fuzzy numbers is crisp in nature

4.5 TOPSIS

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was firstly introduced by Hwang and Yoon. It is highly useful in multi-criteria decision-making (MCDM). The fundamental concept of this approach is that the chosen alternative must have the smallest geometric distance measured from the Positive ideal solution (PIS) and the largest geometric distance measured from Negative ideal solution (NIS). Benefit criteria maximisation and cost criteria minimisation are done in 'PIS' whereas Benefit criteria minimisation and cost criteria maximisation are done in 'NIS'. The 'TOPSIS' method considers that every criterion has a trend of monotonically decreasing or increasing utility. Therefore, it is simple to define the ideal and negative ideal solutions. The Euclidean distance technique was suggested for calculating the relative distance of each alternative from the 'ideal solution'. Thus, the order in alternatives should be ranked can be determined by a series of comparison of these relative distances.

4.6 FUZZY TOPSIS

In the conventional TOPSIS approach, the weights of the criteria and the ratings of alternatives are known exactly, and evaluation process is done using crisp values. However, in many real-life situations, decision-making problems are subjected to various objectives, constraints and consequences that are not precisely known. For resolving the ambiguity that is frequently occurring in information from human judgement, fuzzy set theory has been incorporated in many 'MCDM' methods including TOPSIS. Therefore, the Fuzzy TOPSIS approach is suggested where weights of criteria and ratings of alternatives are calculated by linguistic variables expressed by fuzzy numbers to tackle with the insufficiency in the traditional TOPSIS.

The TOPSIS method is a linear weighting technique, which was firstly introduced, in its crisp variant by Chen and Hwang (1992), with reference to Hwang and Yoon (1981). Since then, this approach has been extensively used for solving MCGDM problems in various areas, ranging from designing of robot (Wu and Parkan 1999) to selection of material (Kang and Jee 2000), from the evaluation competitive companies performance (Deng et al. 2000),for evaluating quality of service in airline industry (Tsaur et al. 2002).

There are several applications of fuzzy TOPSIS methodology in the literature. For example, Awasthi et al. (2011) used fuzzy TOPSIS method for choosing sustainable transportation systems when provided information is incomplete or partial (uncertainty). Bao et al. (2012) propose an upgraded hierarchical fuzzy TOPSIS model for evaluation of roadway safety performance. The suggested model provides with a promising, capable decision support system for evaluating the road safety performance in European countries. Liu and Wei (2018) proposed a fuzzy TOPSIS model to evaluate the risk of electrical vehicle energizing for China's infrastructure private-government partnership projects. Han and Trimi (2018) employed a fuzzy TOPSIS Technique and FLINTSTONES (software tool) for generating aggregate scores to evaluate reverse logistics practices in social economics platforms and found four critical criteria, i.e. Customer relation, Usage risk, Quality control, and Review, as reverse logistics performance indicators. Chiu and Hsieh (2016) proposed new analytic process for examining possible human error and provides a strategy for analysing human error using fuzzy TOPSIS. Wang et al. (2014) evaluated financial performance for container transportation companies situated in Taiwan with fuzzy TOPSIS. Thus a container transportation company can realize its finance competitive strength and weakness between them.

4.7 THE FUZZY TOPSIS METHODOLOGY ALGORITHM

In this paper, the extension of 'TOPSIS' method is regarded which was introduced by Chen.

Step 1: Collect the required data containing linguistics terms. A conventional scale must be chosen to represent the data correctly and more precisely. Respondents must be requested to pick up the best alternative among the linguistics terms for a given question. Linguistics terms must be converted into the fuzzy number. For example Triangular fuzzy numbers are used for this study and a five-point scale with following linguistic terms are being selected:

I. Low (L)

II. Fairly Low (FL)

III. Medium (M)

IV. Fairly High (FH)

V. High (H)

Triangular fuzzy numbers are used because it is considerably easy for the respondents to respond using it. The fuzzy number of each linguistic term is defined with the help of Fig. 2. Fuzzy numbers for the selected linguistics terms are presented in Table.4.1

Table 4.1 Linguistics terms and corresponding fuzzy number

Linguistic term	**Fuzzy number**
Low	(0.0,0.1,0.3)
Fairly low	(0.1,0.3,0.5)
Medium	(0.3,0.5,0.7)
Fairly high	(0.5,0.7,0.9)
High	(0.7,0.9,1.0)

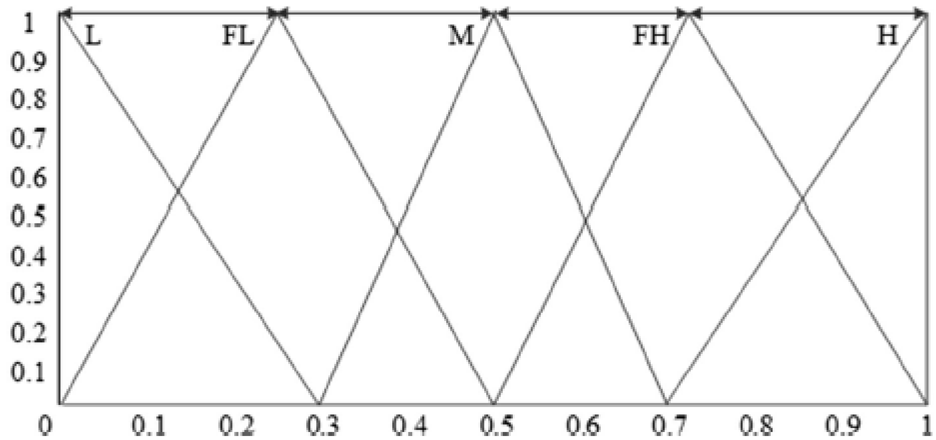

Fig.4.2 Linguistics scales and triangular fuzzy numbers triangular fuzzy numbers (Agrawal et al. 2016)

Step 2: The TOPSIS method evaluates the following fuzzy decision matrix.

$$D = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1j} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2j} & \dots & d_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ d_{i1} & d_{i2} & \dots & d_{ij} & \dots & d_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ d_{m1} & d_{m2} & \dots & d_{mj} & \dots & d_{mn} \end{bmatrix}$$

Where $d_{ij}(= (a_{ij}, b_{ij}, c_{ij})$ is a 'fuzzy number' resembling the 'linguistic term' assigned by the ith Decision Maker (DM) to the jth factor. i = 1, 2…, m. are representing number of 'DMs' and j = 1, 2…, n. representing the number of factors (Barriers).

Step 3: This step involves neutralizing the weight of decision matrix and generating fuzzy un-weighted matrix (R).Normalization is necessary because it is required that all quantities being compared must be on the same scale; this is the basic necessity of any comparison.

To generate R, following relationship can be applied:

$$R = [r_{ij}]_{m\times n},$$

$$r_{ij}=\left(\frac{a_{ij}}{c_j^*},\frac{b_{ij}}{c_j^*},\frac{c_{ij}}{c_j^*}\right), \quad (4.1)$$

Where $c_j^* = \max c$

The normalization of fuzzy decision matrix has two purpose: on the one hand, normalization is necessary to analyze heterogeneous criteria, on the other, normalization assures that 'triangular fuzzy numbers' all range within the interval [0, 1].

Step 4: Calculation of weighted normalized decision matrix

$$V = [v_{ij}]_{m\times n};$$

i=1, 2, 3…, m; j=1, 2…, n.

The 'weighted normalized value.v_{ij} is calculated as.

$$v_{ij} = r_{ij} * w_j; \quad (4.2)$$

Where, w_j is the weightage given to individual decision maker $w_j = (1,1,1,1,1)\forall j \in n$, because all the DMs are considered to have same weight for this study.

Step 5: Determine the Positive ideal solution (PIS) and Negative-ideal solution (NIS) for the barriers

$$A^* = \{v_1^*, v_2^*, \ldots . v_n^*\}$$

$$A^- = \{v_1^-, v_2^-, \ldots . v_n^-\}$$

Since the positive and negative ideas introduced by Chen (1997) are used for the research. The following terms are used for ideal and negative ideal solution.

$$v_j^* = (1,1,1)$$

$$v_j^- = (0,0,0)$$

Step 6: Calculate the distances from 'positive ideal solution' (PIS) and 'negative ideal solution'(NIS) for each factor.

$$D_j^* = \frac{\sum_{i=1}^{m} d(v_{ij} - v_i^*)}{m}, \tag{4.3}$$

j= 1, 2… n

$d(v_{ij} - v_i^*)$ is the distance between two 'fuzzy numbers'. Vector algebra has been used for calculating distances between the fuzzy numbers. For example distance between two numbers A1 (a_1, b_1, c_1) and A2 (a_2, b_2, c_2) can be calculated as

$$d(A_1 - A_2) = \sqrt{\frac{1}{3}[(a_2 - a_1)^2 + (b_2 - b_1)^2 + (c_2 - c_1)^2]} \tag{4.4}$$

Similarly, the separation from the negative ideal solution is given as:

$$D_j^- = \frac{\sum_{i=1}^{m} d(v_{ij} - v_i^-)}{m}; \tag{4.5}$$

j=1, 2… n

Step 7: In this step, the relative closeness to the ideal solution is calculated. The relative closeness concerning A* is determined as

$$C_j = \frac{D_j^-}{(D_j^* + D_j^-)} \tag{4.6}$$

$$C_j \in [0,1]$$

Step 8: Ranking the barriers based on the order of the values of C_j.

CHAPTER 5

APPLICATION OF FUZZY-TOPSIS METHODOLOGY

5.1 INTRODUCTION

In this chapter a case study for implementation of flexible manufacturing system in Indian Automobile Industry is presented. The Fuzzy TOPSIS methodology is used for the ranking of barriers which company face during implementation of 'FMS' so that company may reduce lead time and increase profit.

5.2 COMPANY PROFILE

The first decision maker (D1) is a Senior Engineer in an automotive part manufacturing company, **OMAX AUTOS LIMITED**. DM1 has the responsibility of managing various operations of the industry. The company was established in 1983 and specializes in the manufacturing of 'sheet metal components', 'tubular components' and 'machined components'. By mainly focusing on performance, the company is amongst the prime OEM (parts and assembly) suppliers.

The company has an annual turnover of INR 1042.22 crore (160.74 M USD) in Financial Year 2016-17, it has over 450+ Executive staff and various international accreditations. It has robust manufacturing process capabilities and the vast range of modern machinery and manufacturing facilities intended to give maximum yield as per customer's specifications.

Some of the key strength of company:

i. Turn-over 1300 crores 260m USS year 2012 and several international accreditations
ii. It covers 40 % of Market share for 'Piston Rods of Shock absorber' in domestic Passenger Car Industry.
iii. Among the top companies in automotive stamping, ranging from IOT•1200T covering 0.4mmb 12nun.
iv. Largest and full spectrum welding in India with SPM's & robots.

v. Having Six Fully Automatic plants for powder / ED coating.

vi. 20 % Market share two-wheeler frames in domestic two-wheeler industry.

vii. Largest Medium & Heavy Commercial Vehicle fame assembly supplier in India.

viii. One of the largest Sprocket manufacturing and Tri Nickel Chrome plating facility.

ix. In-house Precision tube mill facility covering diameter 12num to 28 mm, Thickness ranging 06 mm to 2 mm.

x. Largest machining for Precision Engine Components.

The company features in the report of top 10 automobile component makers in India. In India, the company has nine modern manufacturing plants at Dharuhera, Sidhrawali, Manesar, Bangalore, Binola, Lucknow, Pant Nagar, and Bawal. OMAX is also an authorized supplier for 'Indian Railways' and holds expertise in producing various railway products. The company has got a series of national and international accreditations, making it reach a successful pedestal, at a global stature.

The Second Decision-maker (D2) and **third Decision- maker (D3)** are Senior Engineer and Assistant Manager respectively in **JAMNA AUTO INDUSTRIES** respectively. The company is one of the largest in India, and amongst the world, it is the third largest manufacturer of tapered leaf springs and parabolic springs for automobiles. It was the first company to launch parabolic springs in India. The vision of the company to grow as a worldwide leader in Automobile Suspension Solutions. The Company has increased its variety by adding Lift Axle and Air Suspension products under the industrial partnership with Ridewell Corporation, USA.

Mr Bhupinder Singh Jauhar headed the Company. He began the Tapered Leaf Spring business in 1954 in a tiny shop in Yamuna Nagar which was transformed in the company form in the year 1965. Mr Jauhar is presently the non-executive Chairman of the committee of the company. The Company have 9 strategically positioned production facilities at Yamuna Nagar, Jamshedpur, Malanpur, Pune, Chennai, Pilliapakkam, Hosure and Pant Nagar, Lucknow. It is a leader in the market with over 64% share in the domestic OEM market segment and manufactures over '410' modes of springs for OEMs. The

Company has domestic R&D Centre capable of designing Multi Parabolic Leaf Springs, Lift Axles and Air Suspension for all automobile applications. The R&D Centre has the facility of in-house validation and examination of products using 'Servo Actuator' to resemble actual vehicle conditions.

The Company's engineering & design strength and developmental capabilities make it a partner of choice with most of customers. The Company's R&D team work closely with customers in design modification and value engineering in Tapered Leaf and Parabolic Springs which enhance the vehicles' 'load bearing capacity' and 'overall efficiency'. The Company seeks a policy of sustained technical excellence to provide good quality products, parts and services to customers.

The Fourth decision-maker (D4) is a Senior Engineer in an automotive part manufacturing company, '**MK AUTOINDIA LIMITED'**. The company has above '55' years of expertise in manufacturing. The company manufacturer & supply automotive Clutches Assembly, Clutch Plates, Brake Shoes, Brake Pads, Brake Linings, Pressure die-casting, Forging, Machining and Sheet metal components. The company has been recognized as a leading brand in Indian & Overseas automotive market.

The company has six states of the art Clutch & Brake manufacturing Plants in Northern India including a world-class setup at Faridabad (Haryana), a Joint Venture with Chongqing Lide Industry, China, the one of the biggest Clutch Assembly manufacturer in China for two & three wheeler. It has also attached up with the Global leaders 'MIBA', Austria for Paper Friction Technology. The company holds the capability to design, develop, test and validate Clutch Assemblies, Brake Shoes and Brake Pads. It provides complete the solution for two & three wheeler Clutch Assemblies. The company is among the most experienced automotive Clutch & Brake manufacturing company in India, and is recognized for their innovation, technology & manufacturing and thus resulting in market leadership.

The fifth decision-maker (D5) is the Assistant Manager in **SATYAM AUTO COMPONENTS PVT. LTD**. The company is a world-class producer of Motorcycles Chassis, Welded Sub-Assemblies, and Fuel Tanks for 2 and 4 wheelers and Brake Booster

Assemblies. It has an annual turnover of 135 Million USD in the Financial Year 2016-17, it has more than 3500+ Manpower. The company have manufacturing plants which are strategically located in IMT Manesar, Haridwar, Ludhiana and Dharuhera.

5.3 CASE ILLUSTRATION:

Step 1:

In first step a panel of five experts from the case company is selected as per their experience and role in management of company. They are we denoting here D1, D2, D3, D4 and D5 respectively.

Step 2: The important criteria used, are identified based on literature. The criteria used are

- Skilled Labor
- Poor efficiencies of equipment
- Floor layout problem
- Deadlock
- Tool management decisions
- Collisions in automatic guide vehicle
- Tool allocation
- Machine loading problem
- Complexity in Scheduling
- Excessive Tool Switching
- Design and planning problems
- Part type selection problem
- Capacity allocation problem
- Resource allocation problem
- Machine Grouping Problem
- High Initial Capital Cost
- Tool management decisions

They are denoted by C1, C2, C3, C4, C4, C5, C6, C8, C9, C10, C11, C12, C13, C14, C15, C16, and C17 respectively

Step 3: Five decision makers were asked to weight the criteria according to the provided linguistic variable as per Table no.4

Table 5.1: Fuzzy rating of Criteria given by decision makers

Criteria	Name(of criteria)	D1	D2	D3	D4	D5
C1	Capacity allocation problem	FH	H	M	FH	H
C2	Machine Grouping Problem	H	M	FH	H	M
C3	Routing mix problem	L	M	FL	L	FL
C4	Machine loading Problem	FH	M	H	FH	FH
C5	Tool management decisions	L	FL	M	L	FL
C6	Collisions in automatic guide vehicle	M	L	FL	L	L
C7	Complexity in Scheduling	H	FH	FH	M	H
C8	Floor Layout Problem	FH	H	M	FH	H
C9	Skilled Labor	H	M	H	H	H
C10	Resource allocation problem	H	FH	H	H	M
C11	Excessive Tool Switching	FH	H	M	M	M
C12	Selection of material Handling system	FL	L	L	FL	L
C13	Part type selection problem	M	FH	M	FL	FL
C14	Deadlock	M	L	M	M	FH
C15	Government Policies	FH	H	M	M	H
C16	High Initial Capital Cost	H	H	FH	H	H
C17	Poor efficiencies of equipment	FL	L	FL	M	L

Step 4: This step involves neutralizing the weight of decision matrix and generating fuzzy un-weighted matrix (R).

Table 5.2: Fuzzy Un-Weighted Decision Matrix

Criteria	D1	D2	D3	D4	D5
C1	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.7,0.9,1.0)
C2	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)
C3	(0.0,0.1,0.3)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.0,0.1,0.3)	(0.1,0.3,0.5)
C4	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
C5	(0.0,0.1,0.3)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.1,0.3,0.5)
C6	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.1,0.3,0.5)	(0.0,0.1,0.3)	(0.0,0.1,0.3)
C7	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.7,0.9,1.0)
C8	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.7,0.9,1.0)
C9	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
C10	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.3,0.5,0.7)
C11	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
C12	(0.1,0.3,0.5)	(0.0,0.1,0.3)	(0.0,0.1,0.3)	(0.1,0.3,0.5)	),0.1,0.3)
C13	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.1,0.3,0.5)
C14	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.5,0.7,0.9)
C15	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.7,0.9,1.0)
C16	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
C17	(0.1,0.3,0.5)	(0.0,0.1,0.3)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.0,0.1,0.3)

Step 5: Calculation of Un-weighted normalized decision matrix

Table 5.3: Fuzzy un-weighted normalized decision matrix

Criteria	D1	D2	D3	D4	D5
C1	(0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)
C2	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)
C3	(0.0,0.33,1.0)	0.428,0.714,1.0)	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)
C4	0.55,0.77,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)	0.55,0.77,1.0)	0.55,0.77,1.0)
C5	(0.0,0.33,1.0)	(0.2,0.6,1.0)	0.428,0.714,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)
C6	0.428,0.714,1.0)	(0.0,0.1,0.3)	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.0,0.33,1.0)
C7	(0.7,0.9,1.0)	0.55,0.77,1.0)	0.55,0.77,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)
C8	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)
C9	(0.7,0.9,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
C10	(0.7,0.9,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)
C11	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)
C12	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)	(0.0,0.33,1.0)
C13	0.428,0.714,1.0)	0.55,0.77,1.0)	0.428,0.714,1.0)	(0.2,0.6,1.0)	(0.2,0.6,1.0)
C14	0.428,0.714,1.0)	(0.0,0.33,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)
C15	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)
C16	(0.7,0.9,1.0)	(0.7,0.9,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
C17	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)	0.428,0.714,1.0)	(0.0,0.33,1.0)

Step 6: Considering the equal weight for each decision maker, the weighted normalized decision matrix is computed by multiplying the importance weights of evaluation criteria and the values in the normalized fuzzy decision matrix. This is shown in table no 6.4

Table 5.4: Weighted normalized decision matrix

Criteria	D1	D2	D3	D4	D5
C1	(0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)
C2	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)
C3	(0.0,0.33,1.0)	0.428,0.714,1.0)	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)
C4	0.55,0.77,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)	0.55,0.77,1.0)	0.55,0.77,1.0)
C5	(0.0,0.33,1.0)	(0.2,0.6,1.0)	0.428,0.714,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)
C6	0.428,0.714,1.0)	(0.0,0.1,0.3)	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.0,0.33,1.0)
C7	(0.7,0.9,1.0)	0.55,0.77,1.0)	0.55,0.77,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)
C8	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)
C9	(0.7,0.9,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
C10	(0.7,0.9,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)
C11	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)
C12	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)	(0.0,0.33,1.0)
C13	0.428,0.714,1.0)	0.55,0.77,1.0)	0.428,0.714,1.0)	(0.2,0.6,1.0)	(0.2,0.6,1.0)
C14	0.428,0.714,1.0)	(0.0,0.33,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)	0.55,0.77,1.0)
C15	0.55,0.77,1.0)	(0.7,0.9,1.0)	0.428,0.714,1.0)	0.428,0.714,1.0)	(0.7,0.9,1.0)
C16	(0.7,0.9,1.0)	(0.7,0.9,1.0)	0.55,0.77,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
C17	(0.2,0.6,1.0)	(0.0,0.33,1.0)	(0.2,0.6,1.0)	0.428,0.714,1.0)	(0.0,0.33,1.0)

Step 7: In this step, the n-dimensional separation distances of each alternative i =1, . . . , m to the fuzzy Positive Ideal Solution di+ and to the fuzzy Negative Ideal Solution di- are computed according to Eq. (4.5), (4.6) and ,as shown in Table no. 5.5.

Table 5.5: Distance of alternative from A+ and A-

Criteria	Name(of Criteria)	D*	D-
C1	Capacity allocation problem	0.2635848	0.8184648
C2	Machine Grouping Problem	0.2790744	0.8097364
C3	Routing mix problem	0.5583868	0.6666848
C4	Machine loading Problem	0.2854252	0.8022972
C5	Tool management decisions	0.5583868	0.6666848
C6	Collisions in automatic guide vehicle	0.6302262	0.5665736
C7	Complexity in Scheduling	0.2635848	0.8184648
C8	Floor Layout Problem	0.2635848	0.8184648
C9	Skilled Labor	0.219904	0.8508
C10	Resource allocation problem	0.2417444	0.8346324
C11	Excessive Tool Switching	0.3164044	0.7848404
C12	Selection of material Handling system	0.6235336	0.6380364
C13	Part type selection problem	0.4126036	0.73271
C14	Deadlock	0.4188812	0.731296
C15	Government Policies	0.2790744	0.8097364
C16	High Initial Capital Cost	0.2044144	0.8595284
C17	Poor efficiencies of equipment	0.5583868	0.6666848

Step 8: In this step each criteria closeness index is calculated by following formula the optimal criteria have value closeness index closer to 0. According to the closeness coefficient, the ranking of the Criteria can be determined as shown in Table no. 5.6

$$C_j = \frac{D_j^-}{(D_j^* + D_j^-)}$$

$$C_j \in [0,1]$$

Table 5.6: Closeness coefficient and ranking

Criteria	Name(of criteria)	D*	D-	C	Ranking
C1	Capacity allocation problem	0.2635848	0.8184648	0.756402294	5
C2	Machine Grouping Problem	0.2790744	0.8097364	0.743688802	8
C3	Routing mix problem	0.5583868	0.6666848	0.544200682	15
C4	Machine loading Problem	0.2854252	0.8022972	0.73759371	9
C5	Tool management decisions	0.5583868	0.6666848	0.544200682	14
C6	Collisions in automatic guide vehicle	0.6302262	0.5665736	0.473407165	17
C7	Complexity in Scheduling	0.2635848	0.8184648	0.756402294	6
C8	Floor Layout Problem	0.2635848	0.8184648	0.756402294	4
C9	Skilled Labor	0.219904	0.8508	0.794617373	2
C10	Resource allocation problem	0.2417444	0.8346324	0.775409132	3
C11	Excessive Tool Switching	0.3164044	0.7848404	0.712684773	10
C12	Selection of material Handling system	0.6235336	0.6380364	0.505747917	16
C13	Part type selection problem	0.4126036	0.73271	0.63974618	12
C14	Deadlock	0.4188812	0.731296	0.635811595	11
C15	Government Policies	0.2790744	0.8097364	0.743688802	7
C16	High Initial Capital Cost	0.2044144	0.8595284	0.807870874	1
C17	Poor efficiencies of equipment	0.5583868	0.6666848	0.544200682	13

Now criteria (barriers) are rated according to value of closeness coefficient. In table 5.6 Criteria C16 has value of closeness coefficient much nearer to 1, so it is ranked first while the value of closeness coefficient for C6 is farthest from 1, so it is ranked last. In this way all other criteria (barriers) are also ranked according to value of their closeness coefficients.

5.4 RESULT & DISCUSSION

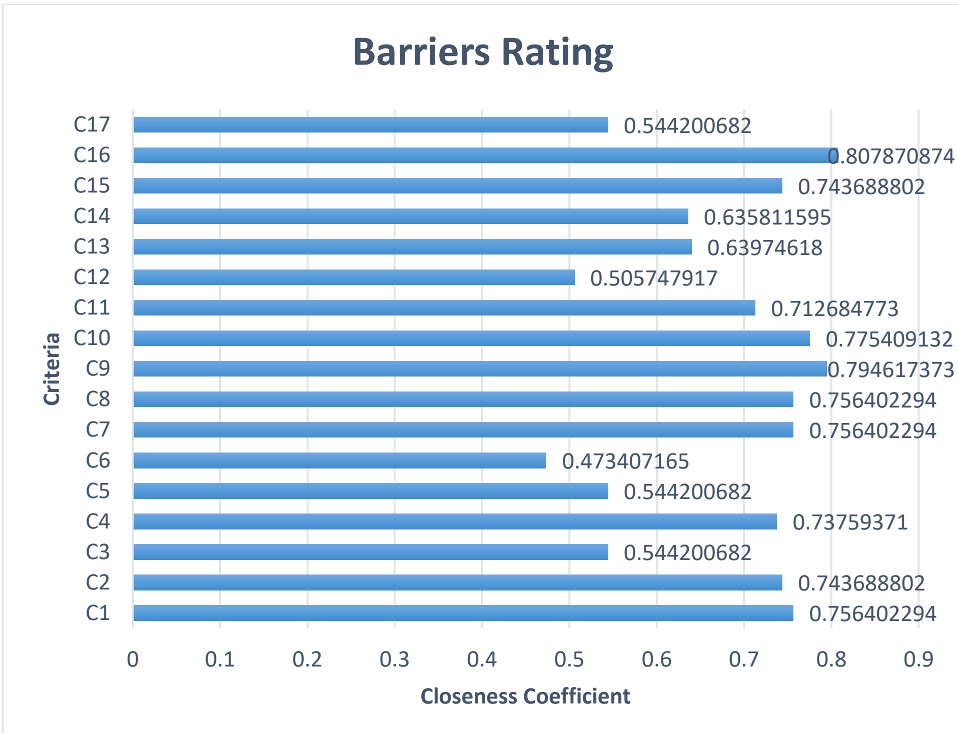

Fig 5.1 Impact Rating of Barriers

Table 5.6 and Fig. 5.1 show the importance ratings of all Criteria (barriers) based on their relative closeness to ideal solution and noticed that the criteria C16 has higher impact over implementation than others. Thus, the primary focus of a company should be on High Capital Cost.

As mentioned in the fuzzy-TOPSIS methodology, the steps involve the collection of response from the several experts in linguistic form, then 'triangular fuzzy numbers' were used to convert linguistics variable into the fuzzy numbers. By converting the fuzzy linguistic variables into triangular fuzzy numbers using Table No, the fuzzy decision matrix D was obtained. In the subsequent step 'unweighted fuzzy decision matrix' R was enumerated.

Additional steps include obtaining the 'weighted fuzzy normalized decision matrix', to find the ideal and negative-ideal solutions for each criterion. The distance D- and D* of each Criteria is derived, respectively, by using Eqs. (4.3), (4.4), and (4.5) .The closeness coefficient C for each criterion is obtained by using Eq. (4.6). Values of D, D* and closeness coefficient C for each criteria are shown in Table 5.6.

The overall prioritization of Criteria (Barriers) are

C16 > C9 > C10 > C8 > C1 > C7 > C2 > C4 > C11 > C14 > C13 > C17 > C5 > C3 > C12 > C6

CHAPTER 6

CONCLUSION & FUTURE SCOPE

6.1 CONCLUSION

FMS intensifies the firm's competitiveness and promotes its position in the competitive market. However, the company may commit common mistakes in the adoption of the FMS system which lend company into trouble and substantial losses. The present framework for identification of barriers work will help the organization to make the correct decision in the adopting the FMS system.

This Work provides the valuable information on FMS implementation for Indian Automobile industry. The research identified 17 barriers for FMS implementation in Indian Automobile industry. The identified factors are somewhat similar to those identified by various researchers all over the world. Still, factors like High initial capital cost, Government Policies, and skilled workers are rarely included in other studies. Analysis of the findings shows that top four prioritized factors High initial capital cost, skilled workers, Resource allocation problem, and Floor layout problem are the most important among all 17 factors. Briefly, the contributions of this study are summarized as follows:

(a) The study provides the insight into previous research on FMS implementation.

(b) Identifies the barriers based on past literature review and experts opinion for successful implementation of FMS.

(c) The research work proposes a framework for evaluating and prioritizing the barriers by using Fuzzy-TOPSIS methodology for FMS implementation.

(d) The study will help the managers and practitioners implementation of FMS. It will enable the managers in identifying the factors which they need to work out for successful implementation.

The findings of the research will help the managers and academicians in the development of FMS strategies and practices in Indian Automobile industry. These barriers can also be used for FMS implementation in other sectors of Indian industry.

6.2 FUTURE SCOPE

Like other studies; this study also has some limitations. This study is conducted using five experts from the Indian Automobile industry. Future studies may consider larger sample size to assess the methodology and the effectiveness of the proposed solution to enable generalization. Furthermore, the wider rating of the 7 or 11-point linguistic scale could be used instead of using a 5-point linguistics scale. Researchers may utilize other methodologies including other MCDM methodologies and may compare the results. Future studies may be carried out to identify company-specific or product-specific identification of Barriers for FMS implementation.

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