ANALYSIS AND IMPLEMENTATION OF CELLULAR MANUFACTURING SYSTEM AND ITS IMPACT ON MANUFACTURING FLEXIBILITY

THESIS

Submitted in fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

To

J. C. BOSE UNIVERSITY OF SCIENCE & TECHNOLOGY, YMCA

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CANDIDATE’S DECLARATION

I hereby declare that this thesis entitled **ANALYSIS AND IMPLEMENTATION OF CELLULAR MANUFACTURING SYSTEM AND ITS IMPACT ON MANUFACTURING FLEXIBILITY** *by* **SANJAY KUMAR,** being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in MECHANICAL ENGINEERING under Faculty of Engineering and Technology of J. C. Bose University of Science & Technology YMCA Faridabad, during the academic year 2017-18 is a bonafide record of my original work carried out under guidance and supervision of **DR. VASDEV MALHOTRA, ASSOCIATE PROFESSOR, SUPERVISOR, DEPARTMENT OF MECHANICAL ENGINEERING AND DR. VIKAS KUMAR, PROFESSOR, CO-SUPERVISOR DEPARTMENT OF MECHANICAL ENGINEERING, J. C. BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA FARIDABAD, HARYANA, INDIA** and has not been presented elsewhere.

I further declare that the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or any other university.

Sanjay Kumar

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This is certify that this Thesis entitled **ANALYSIS AND IMPLEMENTATION OF CELLULAR MANUFACTURING SYSTEM AND ITS IMPACT ON MANUFACTURING FLEXIBILITY** by **SANJAY KUMAR,** submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in **DEPARTMENT OF MECHANICAL ENGINEERING** under Faculty of Engineering and Technology of J.C. Bose University of Science & Technology YMCA Faridabad, during the academic year 2017-18 is a bonafide record of my original work carried out under my guidance and supervision.

I further declare that to the best of my knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or any other university.

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Sanjay Kumar

ABSTRACT

The customer demands change continuously is creating a requirement for new technology of manufacturing systems. In order to survive in competitive and dynamic markets, Industries should have sufficient flexibility to produce a range of products on the same platform As from study it may conclude, cellular manufacturing systems are required to fabricate with filtering economical background as well as engineering concerns; without it they will not be able to get a remarkable share of competitive market to prove their investments. Cellular manufacturing systems (CMSs) are formulated to deliberately produce different product families in the shortest time and with different machine cells at the lowest cost without compromising with the quality. The major characteristic of such systems is called flexibility, which is the ability of manufacturing and changing manufacturing items directed at tailoring the new environmental and technological changes.

There are various factors, enablers and barriers of cellular manufacturing system (CMS) which play a dynamic role in its execution. In this research work, numerous factor, enabler, and barrier of CMS have been enlisted and analyzed. For this purpose, a literature review of CMS has been conducted for identification and to understand the vital role of these factors, enablers and barriers.

In this research work, firstly a questionnaire based survey was conducted on cellular manufacturing system in Indian industries for data collection on various issues related with CMS. Then obtained questionnaire was validated by Analysis of Variance (ANOVA) Analysis. The factors and barriers have been analyzed by Interpretive Structural Modelling (ISM). In this approach a set of dissimilar, straight and circuitously variables are structured into a widespread methodical model. Afterwards, Total Interpretive Structural Modelling (TISM) approach has been applied to understand the relationship and dependency among the enablers of cellular manufacturing system. Analytical hierarchy process have been used to identify the best manufacturing system by comparing the suitability index for the alternatives with sub criteria. Furthermore, entropy approach has been applied for identification of CMS criteria weightage. In addition to, Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) and Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) analysis have been utilized to calculate the ranking of CMS facilitators.

The study will help the future researchers in the area of cellular manufacturing to improve and to have better understanding of the cellular manufacturing system. Moreover, this study suggests an action plan for policy makers in government and industry to help CMS implementation in India.

Keywords: Cellular Manufacturing System (CMS), Factors, Enablers, Barriers, Facilitators, Analysis of Variance (ANOVA), Interpretive Structural Modelling (ISM), Total Interpretive Structural Modelling (TISM), Entropy approach, Multi-Objective Optimization on the basis of Ratio Analysis (MOORA), Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Analytic Hierarchy Process (AHP).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
CMS	Cellular Manufacturing System
ANOVA	Analysis of Variance
ISM	Interpretive Structural Modeling
TISM	Total Interpretive Structural Modeling
MOORA	Multi-Objective Optimization on the basis of Ratio Analysis
VIKOR	Vlsekriterijumska Optimizacija I Kompromisno Resenje
MCDM	Multi Criteria Decision Method
DOF	Degree of Freedom
CNC	Computer Numerical Control
DMS	Dedicated Manufacturing System
FMS	Flexible Manufacturing System
GT	Group Technology
PFA	Product Flow Analysis
AHP	Analytic Hierarchy Process
SS	Sum of Squares
MS	Mean of Square
SSIM	Structural Self Interactive Matrix
RM	Reachability Matrix
MICMAC	Matriced’ Impacts Croises-Multiplication Applique an Classment
En	Enabler
RS	Reachability Set
AS	Antecedent Set
IS	Intersection Set
GTA	Graph Theoretic Approach
DEA	Data Envelopment Analysis
GRA	Grey Relational Analysis
PSI	Preference Selection Index

LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
ANP	Analytic Network Process
LM	Lean Manufacturing
TM	Traditional Manufacturing
RCI	Random Consistency Index
CR	Consistency Ratio
PV	Priority Vector
Fc	Facilitator
CT	Criteria

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

"Cellular manufacturing" is a practice of manufacturing set up in which there is combination of batch production and product manufacturing incorporating group technique type of production. The main aim of "cellular manufacturing" is to react as fast as imaginable, by making a broad range of similar type of parts, while making as little as scrap as imaginable (Datta et. al., 1992). The requirements of customer are changing frequently in nature enforces to make a strong need for a newer technique of manufacturing systems. For getting the adequate competency and to remain in survival with highly dynamic markets, Industries should have minimum flexibility to respond over a range of products to produce on the shop floor (Singh et. al., 2010). As from above it may conclude, cellular manufacturing systems are the systems that can be adopted to get the production with economic aspects as well as manufacturing concerns; to ensure the existence in the competitive and dynamic environment (Abdul et. al., 1999). Cellular manufacturing systems (CMSs) are the type of manufacturing system which is used to produce different product families based on similarity of operations in the minimum time with different machine cells based on similar processing at the minimum possible cost without negotiating with the quality of the product (Biswas et. al., 2017). The characteristic of this kind of system is known as flexibility, which is the amount of level to respond with the range of products to satisfy the changing needs of the customer. Similarly, system flexibility with adequate production level plays a dominant role in selecting the manufacturing system for particular situation. Cellular manufacturing implicates the practice of several 'cells' in a muster line manner. The cells in this kind of manner are constructed with one or numerous dissimilar machines which complete a particular type of function (Sundharam et. al., 2013). The work piece conveyed from one cell to the adjacent cell, every location finished component of the production system. Always the cell are formulated in a "U-shape" pattern due to the reason that it only permits the administrator to minimum movement and have the capability of more supervision and monitoring of the whole system. The major benefits of “cellular manufacturing” are the amount of flexibility that it has. Figure 1.1 shows the schematic layout of cellular manufacturing system. In this type of manufacturing system product type of layout and process type of layout are combined to add the benefits of both the manufacturing system. Different cells are fabricated like the process layout. The different machines are combined to form the cells.

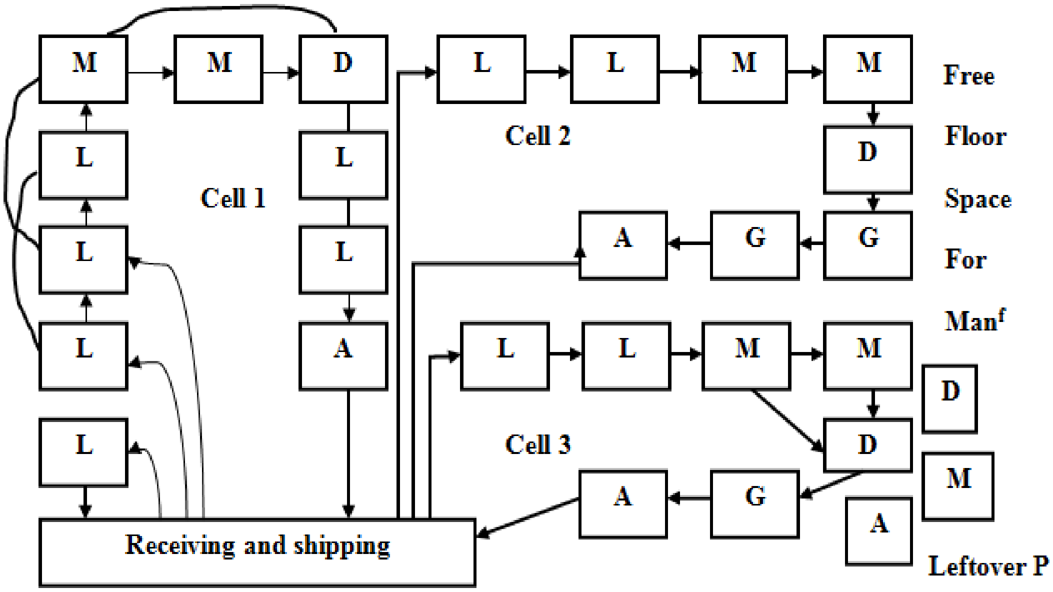

Figure 1.1 Cellular manufacturing system

Merits of Cellular Manufacturing System

The advantages obtained from CMS type of manufacturing system in comparison with old-fashioned manufacturing systems are considered and elaborated here to calculate the performance of the system. The various merits have been discussed here concluded from the past literature, surveys, actual implementations.

- Shortest set up time**:** The manufacturing systems are fabricated in such a type to respond in a quicker time for setup as the machines are arranged in the cells.

Cells are designed according to the similarity in operations so that maximum production can be taken without changing the tools.

- Reduction in lot size**:** with the reduction of setup times in Cellular Manufacturing, small lots are possible and economical. The small lots are provided to respond quickly towards the requirements of the customers.
- Reduced Semi finished and finished goods inventories: Smaller lot sizes are provided in cellular manufacturing system that will results in lesser inventories both at semi-finished and finished level.
- Lower material handling**:** In Cellular manufacturing system, cells are designed to ensure the minimum movements of the material between the machines will lead to the minimum material handling.
- Minimum flow time**:** flow time is minimum in cellular manufacturing system because the cells are designed according to the need of effective processing.
- Lowest possible tooling**:** In cellular manufacturing system cells are designed for the similar types of operations will results into the reduced tooling.
- Requirement of lesser floor area: With the use of cellular manufacturing system minimum inventories are being maintained at semi-finished and finished area so that the floor area required is minimum and efficient.
- Throughput times are reduced: In cellular manufacturing system machines are arranged closed to each other and according the similarity in operation in a cell so that parts are moved quickly from one machine to another leads to lower the throughput times.
- Improved quality of product: cells are designed in the cellular manufacturing system to respond quickly and efficiently against the production and flexibility without compromising with the quality of the product.
- Better control on operations: In cellular manufacturing system different cells are designed according to the available floor, requirement of production and range of products so that in cells the effective supervision and control can be maintained to get the effective utilization of each and every available resource.

1.2 Comparison of Cellular Manufacturing System

The comparison of cellular manufacturing system has been done with other manufacturing system that is dedicated or conventional manufacturing system and flexible manufacturing system

1.2.1 Dedicated manufacturing system

The product type of layout has the arrangement of machines in a line according to the sequence of operation. The various operations on raw material are performed in a sequence. Accordingly the machines are arranged in the sequence of operation performed on the product means on the product flow line. The system has high production rates. The plant is designed for some specific product using some special purpose machines and general purpose machines. It is generally called as mass production type of layout as it generally produces large volume of production. As compared to production layout requirement of skill of workers is somewhat low. The material flow is according to the sequence of operations by material handling equipment's. The time of the product spend at each station is equal and fixed. The workstations are arranged in line.

1.2.2 Flexible manufacturing system

Flexible manufacturing systems were created in the 1960's to achieve a wider variety of production capabilities than traditional dedicated transfer lines. FMSs combine the repeatability of transfer lines with the flexibility of computer numerical control (CNC) machines. In general, FMSs achieve flexibility through the use of programmable software architecture to quickly change work orders and process sequences. Due to this low throughput and the high cost of CNC machines, the FMS fails to deliver an acceptable cost per part. To satisfy the shortcomings of FMSs, cellular manufacturing systems were proposed to deal with the volatile, uncertain market conditions and cost per part requirements of consumers.

A Flexible manufacturing is a manufacturing in which all production elements of manufacturing into a highly automated system. The FMS type of manufacturing system has high flexibility to respond quickly towards the changing needs of customer. The basic components of FMS are a) works station b) material handling, storage, and retrieval systems c) control systems. To survive in the competitive and dynamic environment the reduction in set up time, change over time and improvement in production and flexibility is required. FMS is suitable according to the flexible needs of the customer.

1.2.3 Cellular manufacturing system

In today's competitive environment many companies are motivating to improve their manufacturing performance. It is now universally accepted that cellular manufacturing is one such method that manufacturers can use to help meet their goals, through product and production flexibility, lower costs and improved customer response times. Cellular Manufacturing is based on processing of similar parts are assembled in part families, and clusters of similar operating machines that may be dissimilar in function into the machine cells Providing the adequate level of productivity and flexibility through the different cells.

The comparison between dedicated manufacturing system, flexible manufacturing system and cellular manufacturing system has been shown in the following table1.1

Table 1.1 Comparisons of CMS

S. No.	Criterion	Dedicated manufacturing System	Flexible Manufacturing System	Cellular manufacturing System
1	Hierarchy of Organisation	Traditional type of organisation	Team oriented and synchronous management	Compacted, and team coordination organisation
2	Flexibility in the system	Very Poor respond towards the change	Medium response towards the change	Highly active and quickly respond to the changes.
3	Responsibility towards work	Lack of empowerment, centralised and informal authority	Self-autonomous	Self-autonomous and empowered authorities
4	Type of Manufacturing set-ups	Rigid and more spread area type of manufacturing	Automated type and medium flexible which can respond the change	Flexible and highly sensitive manufacturing and quickly respond to the changes.

5	Quality	Low quality and lesser customer satisfaction	Quality is medium and customer satisfaction is there	Customer satisfaction is the target
6	Production	Lower productivity with no practical evaluation and perfection	Adequate productivity with moderate quality	Rapid productivity with moderate flexibility and high quality
7	Role of Man power	Simple organization and flattened hierarchy with lower skill	Medium skilled and multi-functional man power	multi-skilled and multi-functional and dynamic man power
8	Training of Employees	No training is provided	training is conducted regularly	Employee training is conducted as an integral part of their job responsibility
9	Involvement of Employees	Little involvement of employees in decision making. No employees are entertained to brief their ideas	Lower empowered employees	Fully authorised man power, ideas and knowledge of employees are fully utilised
10	Management	Autocratic and stagnant style of management.	Medium Flexible management	Involvement and responsible management which is liable to changes and improvements.

1.3 CLASSIFICATION OF CELLULAR MANUFACTURING

As the research is related with Cellular Manufacturing system, the introduction and classification of Cellular Manufacturing system are discussed here as follows:

1.3.1 Group technology

Group technology (GT) is a kind of manufacturing idea in which the parts with similar working are grouped together to get the benefits of their similarities in operation. The grouped parts are known as “part family”.

1.3.2 Part family

A part family can be selected with recognition of each and every part in the organization. The parts whose processing are similar or some of operations are identical then these parts are classified in cluster and named as part family which can be processed in the machine cells with greater efficiency and control. The grouping or classification of various parts based on their working can be done by various methods these are as follows:

- Coding and Classification
- Visual inspection
- Production flow analysis (PFA)

1.3.3 Coding and classification

Coding and classification is a process in which the parts are recognized and segregated as per their operation and process. Firstly classification has done and then after coding is assigned to propagate the required information of the system for communication.

The classification is the process of dividing the parts into group on basis of their unique attributes. Part can be classified on the basis of their:

- Design attributes such as major dimensions, minor dimensions, basic external or internal shape, length to diameter ratio, surface finish, tolerances and material used etc. such system is useful for easy design retrieval from database. It also promotes design standardization.
- Manufacturing attributes refers to the manufacturing process, processing equipment required, cutting tools, jig and fixtures required, operation sequence, production time, production rate etc. such system facilitates retrieval of computer aided process plans, tooling designs and other production related data from the existing database.

- Design and manufacturing attributes aims at combining the functions and advantages of above two systems into a single classification method.

Coding refers to the process of allotting a unique symbol to the component. Various coding systems have been developed for specific application. During the implementation phase coding scheme is to be developed and assigned, a proper study and survey is conducted for all parts with their specification to code values for assigning features. The selection of harmonious topographies relies on the solicitation of coding arrangement, based on processing and operation. The coding involves a series of numerals for recognizing the part processing and operation. The coding schemes are as follows:

- OPITZ code
- MICLASS
- DCLASS
- KK3

1.3.4 Visual inspection

The Visual inspection is done on the basis of physical checking and inspection carried by the experts or skilled workers. The visual inspection is the fastest but the least accurate process among the given alternatives. In this method the parts are classified after only their visual checking’s.

1.3.5 Production flow analysis

Product flow analysis is another methodology in GT which uses manufacturing sequence information available on route sheets. The route sheets of components are examined in order to sort through all the components and regroup them by a matrix analysis. New machine cells are formed from the existing machine layout by analyzing flow of material and then reorganizing the machines. Product Flow Analysis was firstly used and developed by J. L. Burbidge. Product flow analysis is developed to analyze the arrangement of operation and machine sequence for the production. In this method the parts are assembled on the basis of similarity in processing. It is used to overcome two possible abnormalities.

- Parts that are having different basic geometries will not require identical process routing.
- Parts that are having same basic geometries will need other processing parameters.

However the weakness of product flow analysis is that this method uses route sheets, without considering given route sheets such as ideal or reliable or even rational type of routings.

1.4 Types of cellular manufacturing system layout

I. **Inter-cell layout:** This kind of arrangement in such a way that it eliminates the part movement between inter-cells. Figure 1.2 shows the schematic diagram of this type of layout.

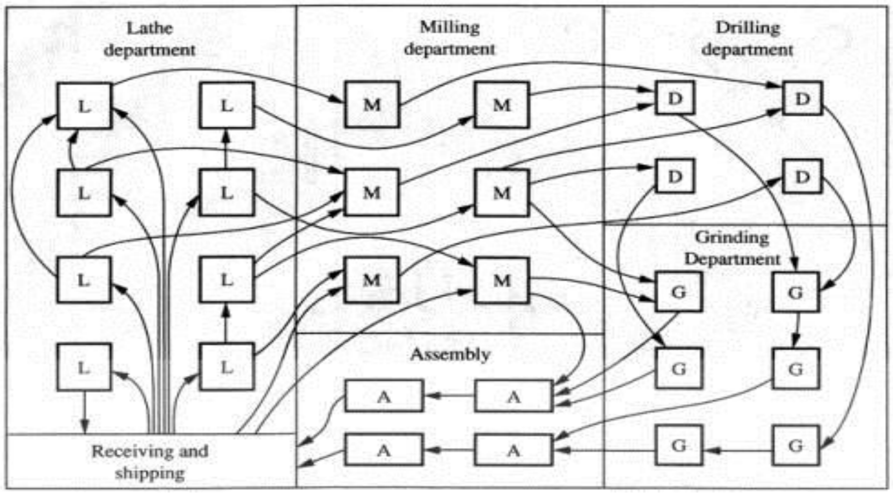

Figure 1.2 IC layout

- **IC layout:** The kind of arrangement in which the machines are arranged in such a way that they remain with in the cell and movement of parts are also restricted to move within the cell. Figure 1.3 shows the schematic diagram of this type of layout.

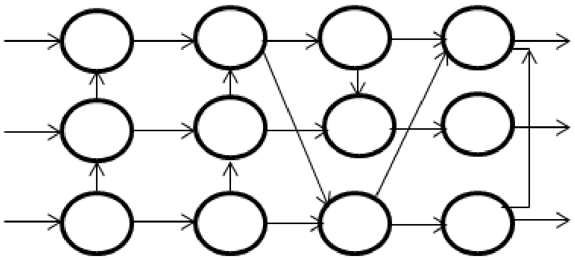

Figure 1.3 Intra-cell layout

1.4.1 Types of intra-cell layout

- **Based on the location of machines**

I. **Particular line layout:** In single row or particular layout machines are settled very close to each other and in a line pattern as per according to the sequence of operation. The single row layout is of many profiles like In-line, semi-circle type or U-shape type. The merits of single row type of arrangements are reduction in material handling, reduction in cost and production time, unidirectional flow, short set up time, effective supervision over various processes and the facility to use conveyors. Figures 1.4, 1.5 and 1.6 shows the In-line, semi-circle and U-shape type of layouts respectively.

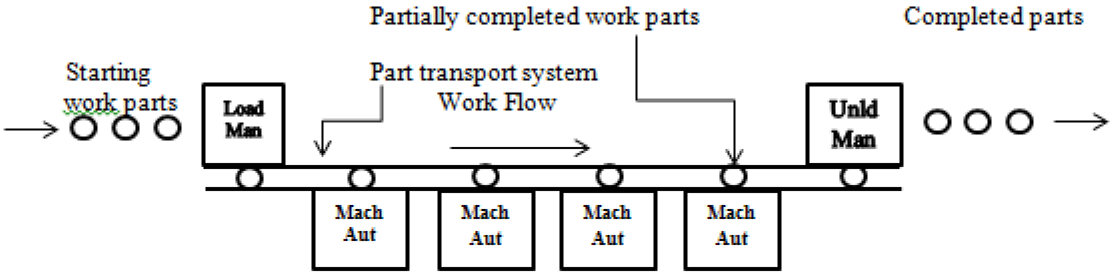

Figure 1.4 In-line layout

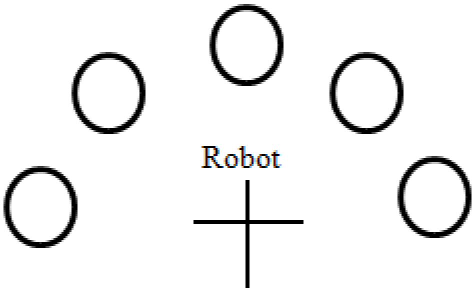

Figure 1.5 Semi-circle layout

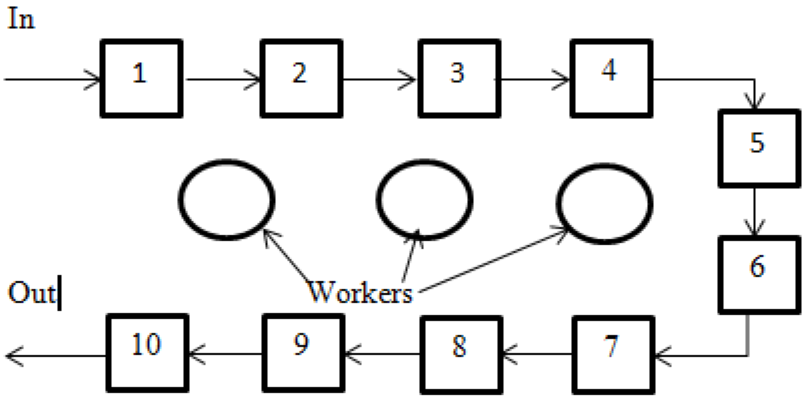

Figure 1.6 U-Shape layout

II. **Multi-line layout:** In this type of arrangement, the machines are grouped in multi-line manner. The machines in each line respond towards each other as well as with the machines in other lines. Figure 1.7 shows the schematic diagram of this type of layout.

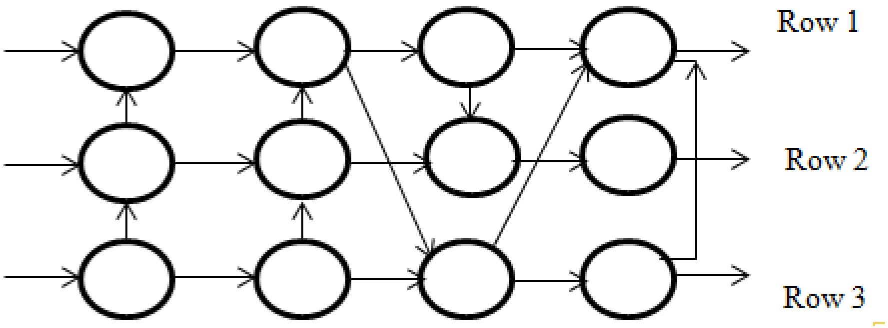

Figure 1.7 Multi-line layout

III. **Loop layout:** In this kind of arrangement, the machines are shuffled over a circular way and the movements of different parts are commonly in same direction. The ideal application of this type of arrangement suits for the adequate flexibility in material handling. Figure 1.8 shows this type of layout.

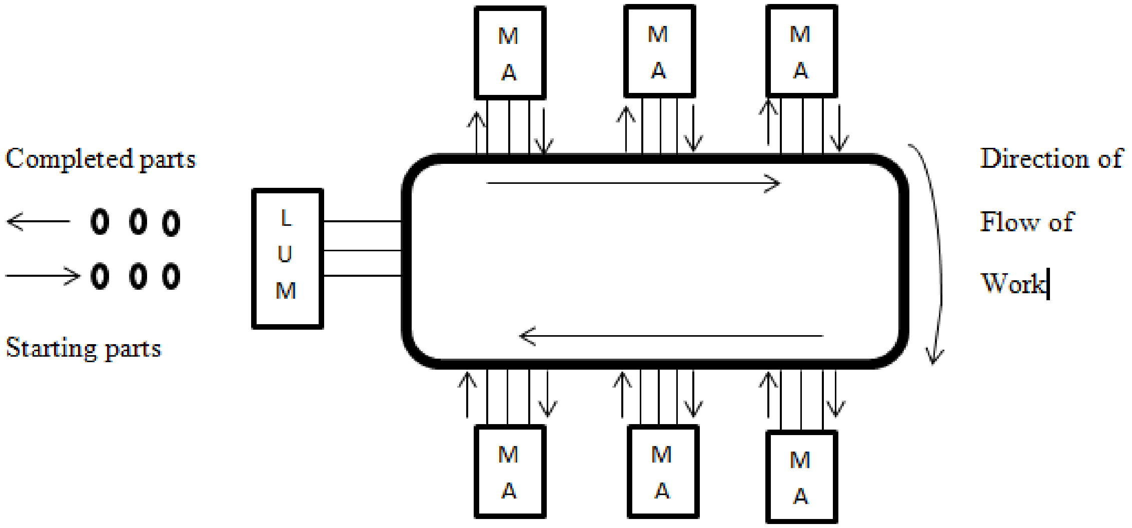

Figure 1.8Loop layout

- **According to environment**

I. **Machine arrangement in fixed nature:** In this type of nature, it does not change over the development phase because there is no difference in the flow of material.

II. **Machine arrangement in flexible nature:** In this type of nature, the layout demands a change due to the following factors:

- Product change
- Different processing sequence for particular part
- Varying demand
- Number of products

In order to survive in said environment changes, sectional apparatus general-purpose construction machines, latest material handling tools, etc., are selected in flexible nature.

1.5. Factors affecting the CMS

"Cellular manufacturing" is a well-organized kind of production system that takes the advantage of both product type and production type of manufacturing system but it is very hard to convert into the cellular manufacturing system from old-style or conservative manufacturing system to CMS. There are numerous components in the manufacturing system that not only affects the system but also influence the system. Thus it is very important to conduct the research related about various elements of cellular manufacturing system. So that for application of CMS in any organization there is necessity to recognize and examining the elements which can affect application of CMS

Factors affecting the implementation of CMS have been found from the literature review and from the questionnaire survey. The factors identified are as follows:

- **Organizational construction**

From the long time structure of management has been found in such a way that its impact on shop floor workers and staff is very low (Malhotra 2015).Organizations that are having flat hierarchy provide a concept of activities of management; increase incoordination, less administration, better infrastructures, and support from workers. Management support with clear organization structure always aids in application of cellular manufacturing system.

- **Employee Training**

Employee training plays a crucial part in incorporation of manufacturing systems in organizations. Statistics of newer technologies and methods incorporate the organizations when there is a need to redesign the present manufacturing system. The numerous determinations those cannot support by documentation work have to be excluded and then to be incorporated using training of employees. Thus the successfully achievement of cellular manufacturing system employee training plays a very governing role.

- **Support from workers**

Role of worker is an important factor which plays a dominant role in CMS. When knowledge's and procedures are not available, organization shall be selected to import the techniques to continue the production (kumar et. al., 2017). Cellular manufacturing system (CMS) shall be fabricated in such a manner that new products or modifications can be introduced with lesser efforts. So for attaining the desired product at lowest possible budget support from workers is a factor of CMS.

- **Support from management**

Mishra (2014) emphasized in getting flexibility in production scenario with a vibrant change on the shop floor. This kind of change in any industry requires a stipulated support of management in respect of availing minimum required fund and various related task. This is a very important factor to withstand the various parameters in the cellular manufacturing system. This factor reacts as a strong gismo for obtaining flexibility in any manufacturing system.

- **Long term planning**

Planning is required to understand the complexity of the system and validation for the existing system is also important (Davis et. al., 1994). In cellular manufacturing system long term planning comprises improvement of a formal and incorporated depiction arrangement. Long term planning in CMS is an important task so that it becomes a significant element of the system.

- **Improved supplier relationship**

For getting the maximum utilization of space and time a healthy interaction with the suppliers is needed in the CMS (Malhotra 2014). Improved supplier relationship is useful for the various proficiency in cost cutting and reduction in lead times (Speredelozzi et. al., 2003).

- **Flexible manpower**

Cellular manufacturing is operated with flexible workforce with a greater efficiency and productivity. It is a potential factor to enhance the productivity and quality of any manufacturing system. In terms of flexible the workers have multi skill to develop more methodologies and coordination's. Factors required for Cellular concert include the facility to manufacture the parts with adequate proficiency and minimum time (Gunasekaran et. al., 2002).

- **Support from Government**

Customer demands are changing continuously in the market. In order to survive the range of products and with high flexibility in the system are required so that changeover can be there for the newer features of the product (Jain and Raj 2015). This type of system can be tailored with competency is directed as a result from the support from the government. Therefore, this can be taken as an important factor of CMS.

- **Multi-Tasking**

Gunasekaran (1999) experienced that multi-tasking is important factor related with flexible work force. Multi-tasking workers are having multiskilling to have a greater interface towards the production they are also multifunctional, self-motivated etc. So that multi-tasking is a key factor in implementation of cellular manufacturing system.

- **Organization plans**

Mishra (2014) emphasized in getting flexibility in production scenario with a vibrant change on the shop floor. This kind of change in any industry requires stipulated plans in respect of availing minimum required fund and various related task. This is a very important factor to withstand the various parameters in the cellular manufacturing system. This factor reacts as a strong gismo for obtaining flexibility in any manufacturing system.

- **Availability of funds**

The funds in an organization play a vital role in any kind of manufacturing system. It is a factor which influences the parameters of an industry. The workers are motivated and being empowered up to level so that maximum efficiency and productivity can be taken to strengthen the forward momentum of an organization by providing the necessary incentives and bonus. In this way it can be treated as a potential factor of cellular manufacturing system.

- **Improved lead time**

Improved lead time means the minimum time to start the production after any kind of breakdown. Organizations are always remaining in completion to provide the products in shortest time and minimum cost. With the help of reduction in lead time organizations can increase the productivity (Dixit et. al., 2013).

- **Reduced defect**

Minimum defect is the fitness of the manufacturing system to adjust efficiently the production volumes minimum price and in minimum period towards an enormous range of manufacturing. Designing manufacturing systems with the features of minimized defect allows management to increase and decrease production capacity quickly and cost effectively in response to market demand (Azzone et. al., 1989). So that reduced defect is an important factor in implementation of CMS.

- **Reduced set up time**

Reduction in set up time is the fitness of the manufacturing system to respond in higher productivity with effective utilization of resources. Manufacturing systems with the features of minimized set up time ensures high production volumes with minimum time (Azzone et. al., 1989). So that reduced set up time is an important factor in implementation of CMS.

- **Floor space utilization**

The floor space is utilized properly in a cellular manufacturing system providing the effective use of available area in the factory. In some of organization it becomes a challenge to utilize the space in an effective manner (Kumar et. al., 2017). So that it becomes an important factor of CMS.

- **Increased safety**

Safety in an organization must be analyzed in regular span of time to ensure the proper liability of the workers. Safety is the first concerned for every industry to ensure the proper working environment to increase the productivity with adequate level of safety (Dixit et. al., 2013).

- **Improved quality**

Quality in an organization develops the competency and level of faith in the mind of customers. To satisfy the customer's quality standards must be followed by the manufacturer (Malhotra 2014). Quality policies are framed to develop better working environment for the workers as well as the end users of the product.

- **Relative profit**

The organizations are continuously struggling in the dynamic competitive environment to earn more and more profit. Profit is the topmost and last important factor for any kind of organization which plays important role during all phases of manufacturing.

1.6. Enablers of Cellular manufacturing system

Enablers are the elements that always support the implementation of cellular manufacturing system. Some of these are as follows:

- **Reduced defect rate**

Productivity is affected with the defect rate in the production. To remain in competitive environment organizations are continuously emphasizing on the reduction of defects in the production. The manufacturing systems are taking interest to acquire a compatible environment to sustain quality with maximum production. Organization should have strong internal environment to react as fast as possible for continuous changing demands of the customers.

- **Reduced work in process**

A cellular manufacturing system is essential to deliver its patrons with a range of products with high quality and good service. Reduced work in process is a healthy mode of relation among the various expectations of the customers with the industries. A reduced work in process will strengthen the relationship and in turn make this as a strong enabler of cellular manufacturing system (Zhang 2011).

- **Flexible staff**

Cellular manufacturing is operated with flexible workforce with a greater efficiency and productivity. It is a potential factor to enhance the productivity and quality of any manufacturing system. In terms of flexible the workers have multi skill to develop more methodologies and coordination’s. Factors required for Cellular concert include the facility to manufacture the parts with adequate proficiency and minimum time (Gunasekaran et. al., 2002).

- **Top level management sustenance**

Mishra (2014) emphasized in getting flexibility in production scenario with a vibrant change on the shop floor. This kind of change in any industry requires a stipulated support of management in respect of availing minimum required fund and various related task. This is a very important factor to withstand the various parameters in the cellular manufacturing system. This factor reacts as a strong tool for obtaining flexibility in any manufacturing system.

- **Arrangement of Organization**

Adequate control is not found in the organizations (Malhotra 2015). Organizations that are having flat hierarchy provide a concept of activities of management; increase in coordination, less administration, better infrastructures, and support from workers. Management support with clear organization structure always aids in implementation of cellular manufacturing system.

- **Reduced lead time**

Reduced lead time plays a crucial part in incorporation of manufacturing systems in organizations. Statistics of newer technologies and methods incorporate the organizations when there is a need to redesign the present manufacturing system. The numerous determinations those cannot support by documentation work have to be excluded and then to be incorporated using reduced lead time. Thus the successfully achievement of cellular manufacturing system reduced lead time plays a very governing role.

- **Increased Automation**

Automation is a critical factor in estimating the performance of any type of manufacturing system. Automation is a main revolutionary force in the success of any organization. It is a potential factor of cellular manufacturing system because the utilization of man power up to maximum extent is the key to the success of an industry.

- **Improved productivity**

Nowadays, the manufacturers are continuously seeking ways and measures to gain competitive advantages. As competition intensifies, they have to enhance their manufacturing flexibility, quality, and costs. Consequently they have become more and more open to new and innovative ideas that are perpetuated to yield competitive gains to increase the productivity (Dixit et. al., 2013).

- **Improved quality**

This is an important enabler which imparts the whole life span of a part. In a cellular manufacturing system, it is essential to get the quality standards in production. The quality is maintained in the system to analyze and to track the particular problems. So that for getting optimum level of inventory, flexibility, quality, and productivity this is an important enabler.

- **Reduced scrap/waste**

The productivity of any manufacturing system is a measure of efficiency in an organization. To remain in competitive environment organizations have to reduce their scrap and waste (Wemmerlov and Hyer 1997). The main enablers of cellular manufacturing system are to reduce WIP inventory, setup time, scrap and material handling, and to improve quality of the product.

- **Reduced set up time**

Reduction in set up time is the fitness of the manufacturing system to respond in higher productivity with effective utilization of resources. Manufacturing systems with the features of minimized set up time ensures high production volumes with minimum time (Azzone et. al., 1989). So that reduced set up time is an important factor in implementation of CMS.

1.7 Barriers affecting cellular manufacturing system

There are various barrier comes in the path of implementation of cellular manufacturing system these are as follows:

- **Factory floor layout**

Factory floor layout is the main obstacle faced during the transition of traditional or some other manufacturing system to cellular manufacturing system. The layout of the factory will play a vital role for the flexibility in change of the production system (kumar et. al., 2017).

- **Lack of advanced machinery**

Lack of advanced machinery is also a important factor which is always resisting the transition phase. Advanced machines like computer numerical control machine will always aid the rate of production and the flexibility of the production system which will make it as an potential barrrier (Malhotra 2014).

- **Material transportation problems**

Material transporatation is a kind of barrier in implementing the cellular manufacturing system. When material is handled and transported over a long distance, manufactring system is selected accordingly (Raj et. al., 2009).

- **Lack of funds**

Fund is a prominent barrier against implementation of cellular manufacturing system. Without funds organization may face number of problems related with the automatic machines, men power etc.

- **Manufacturing Process**

The manufacturing process of a organization plays an important role during the transformation to the cellular manufacturing makes this as an potential barrier. Manufacturing system can aid the implementation process and some manufacturing can also retard to the implementation process or tranfaormation process to the cellular manufacturing system.

- **Other external forces**

With all barriers that affect the implementation and design of cellular manufacturing system some other barriers like external to the system are also plays an imporatant role while dealing with the transformation. External forces on the organizations are like the pressure from the customer end, suppler end and need of the product etc.

- **Management obstacle**

The barrier related with the management is the top most barrier in the path of design and implementation of cellular manufacturing system. The hierarchy will start from the top management. The manufacturing system which is followed in the orgnization is built with the concern of top management. If the management is flexible towards the change in the system it can be treated as a enabler.

- **Workers resistance**

After dealing with the barrier of top management the resistance from the worker is the next crucial barrier in the design and implementation of the cellular manufacturing system. Workers of an organization are directly involved in the physical form of production so they are always resisted towards the change so that workers resistance can be taken as a potential barrier.

- **Lack of Training**

Training is the integrated part of organization. From training the physical and maental strength of the employees are always added up with their skill. There is a need of continuously assistance awareness with the advancement of technologies and newer tools. Training is provided to cop up the strength with the skill of a worker so it is a major barrier in the path of cellular manufacturing system.

- **Lack of Knowledge about GT**

The workers those are working in the cellular manufacturing system area should have minimum knowledge about the working culture of the cellular manufacturing system otherwise the workers always remain in resistance towards the change. Thus lack of knowledge is considered as a barrier in the implementation process of cellular manufacturing system.

- **Lack of support from various departments**

The communication with the various department is required to carryout the healthy production and to responding the required scenerio of the market. The target dates can not be achieved untill a good communication and understandings with various departments. The all above reason makes it an important barrier.

- **Influence of trade unions**

There is always resistance to change from the workers. This resistance got multiplied when there is influence of trade unions behind them. Ultimately when there are trade unions, they always supports the worker and their future securities. Trade unions always influence the wokers and in last this becomes a critical barrier of CMS.

- **Communication barriers with suppliers**

In flexible manufacturing system communication with the suppliers plays an important role during the implementation of cellular manufacturing system. If the communication is not sound then it always retard the momentum of production and quality. Hence it is also an mass barrier in imlementation of cellular manufacturing system.

- **Legislation, regulation and policies of government**

There is always a threat in the mind of organization related about legislation, and policies of government. The organization has to follow some policies laid down by the government and they have to satisfy the norms related with the environment, working culture etc. Hence legislation, regulation and policies of government is become a potential barrier against the implementation of cellular manufacturing system.

1.8 OBJECTIVES OF RESEARCH

The following objectives are defined to work in this study those are:

- To review the literature related to Cellular manufacturing system and find out the future research directions.
- To find out the factors, enablers and barriers that affects the performance of cellular manufacturing system.
- To find the suitability of CMS in Indian industries in comparison of other manufacturing system.
- To determine the weightage criteria and ranking of facilitators.
- To analyze the impact of labor related factors on the performance of cellular Manufacturing.

1.9 ORGANIZATION OF THE RESEARCH

The organization of the research used in studyare as follows:

1.9.1 Survey Conducted based on Questionnaire

A survey based on questionnaire is used to understand the respondents observation based on various issues of the considered problem in the study. The survey has been used to get the more aspects in CMS implementation.

1.9.2 ANOVA Method for Validation

It is a important method deals with the investigators in the areas of engineering, production and management etc. with the help of this method, validation of the data collected from the questionnaire can be obtained. From validation it can be concluded that thae data collected is significant or not.

1.9.3 ISM Technique

This methodology is broadly used to improvethe interrelationship between the complex variables by building the hierarchy from the various iterartions among the variables. The techinique utilizes a set of contradictory, traditional and tangentially variables are structured into a extensive model. The ISM technique is synthesized for introducingdynamic and reliancecontrol of elements affecting CMS.

1.9.4 TISM Approach

This is a method which is used for devloping the correlation among the various enablers of CMS. The TISM approach is generated from ISM approach becoause ISM approach is lacking in providing the understanding of fundamental relations as well as not clear in available circumstances (Jain & Raj 2015). Thus, TISM methodology is usually followed over the practical implications of the ISM. The procedure of TISM approach is elaborated by Sushil (2012). TISM progression pledges along with the documentation of enablers those facilitate the industrial scenario that may be connected with a piece from various elements within a organization. The next step after documentation, which is different from the ISM due to the reason that in TISM we are recognizing the related circumstantial and understanding association (Jayalakshmi & Pramod 2015). Then the relationship among the various enablers are now rehabilitated into a SSIM. Then next to the model, RM was formulated by SSIM. The transitivity is cheked after the step. Transitivity of the circumstantial model is a elementary postulation made in the given technique. Then after this step, partitioning with iteration is developed in concluding reachability matrix. The digraph is developed according to the associations found in the partitioning and also communication matrix is drawn from the developed diagraph. The subsequent communication matrix and digraph is rehabilitated into model of TISM by substituting elements knots with elements (Sushil 2012). In end, the model is tested for hypothetical inconsistency and amendments are inserted in the model.

1.9.5 AHP Technique

The Analytic Hierarchy Process (AHP) is a multi-principles judgment making (MCDM) method that helps the judgment-maker fronting a multifarious problem with multiple contradictory and particular criteria (for example location or investment selection, projects ranking and so forth). The Analytic Hierarchy Process (AHP) is a philosophy of dimension over pairwise judgments and depends on the decision of experts to find out importance scales. These are the gauges that quantify hypothetical factors in virtual terms. The judgements are fabricated using a scale of entire judgments that signifies, how much, one element leads another with respect to a given aspect. The judgments may be jumbled, and how to measure incoherency and improve the judgements, when possible to obtain better coherency 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 (Saaty 2008).

1.9.6 Entropy Approach

Entropy principal is a kind of method in which wieghtage is calculated for the alternatives. It is the easiest technique ever suggested by Shannon in 1948. This methods follows the simplest way for finding the weights of the elements with easy calculations. As from decrease the statistics entropy, weight of concerned alternative is increase due to the reason that in real situation we always choose that value whose doubt level is low (Huang et, al., 2015). This method has more benefits compared to other MCDM method (Rhodes et, al., 1995) is

- The result is reliable with all the existinginformation.
- Time to solve is minimum
- Simple in nature
- Validity can be tested
- Easy calculation

The technique has found the most suitable method in various available MCDM approaches. From literature its applicability and adaptability can be measured and ensured.

1.9.7 MOORA Method: MOORA means Multi-Objective Optimization on the basis of Ratio Analysis. MOORA techniquetacklesinstantaneouslyan optimization of availablecontradictorycommitmentconcern to certain criteria. Technique was familiarized by Brauers in 2004 and suggests that it is a technique in which we can optimize multi-objectives (Brauers et, al., 2006). The technique is synthesizedto get the best alternatives and ranking among the various available inputs. This method is comparativelyguileless method as from other MCDM approaches and it is very easy to deal with the above method. Now this method becomes the most popular method in the researchers.

Merits of MOORA technique (Karande et, al., 2012) is

- Simple in calculations
- Easy to understand
- Consume less time

This method has been found as the most suitable method where reserchers have to find the ranking among the comlex decisions.

1.9.8 VIKOR Analysis:

Vlsekriterijumska Optimizacija I Kompromisno Resenje is the best method to get the best ranking among the various available factors. Opricovic in 1998 elaborated the analysis for finding the optimal solution and ranking of multifariousorganizationwith complex alternatives (Opricovic 1998). Method synthesized to get the ranking orders of theofferedreplacements and permanency of weight across the intermissions of the cooperation solution with initial given weight here derive by entropy method (Opricovic & Tzang 2002). Thetechnique is used to find the best alternative and to provide the ranking among the various possible complex alternatives.

Merits of VIKOR approach

- v factor is depend on the decision maker
- best solution for ranking of the alternatives
- Easy to understand

1.9.9 Graph theoretic approach

A graph may be undirected, meaning that there is no distinction between the two vertices associated with each edge. Graphs are represented graphically by drawing a dot for every vertex, and drawing an arc between two vertices (Rao and Padmanabhan, 2008). Digraph models are based on the structure of the system but are flexible enough to analyze changes. The conventional representations like block diagrams and flowcharts do not depict interactions among factors and are not suitable for further analysis and cannot be processed or expressed in mathematical form. The graph theory approach has some unique features such as it permits modelling of interdependence of factors under consideration, it permits visual analysis and computer processing and it presents a single numerical index for all the factors. It is a systematic methodology for conversion of qualitative factors to quantitative values, and mathematic modelling gives an edge to the proposed technique. It has three elements such as digraph representation, matrix representation, and permanent function representation. The matrix converts the digraph into mathematical form. The permanent function is a mathematical model that helps determine index which is helpful for comparison.

1.10 SIGNIFICANCE OF THE STUDY

The increasing importance and significance of CMS in contemporary manufacturing atmosphere were studied through various research papers. Factors, enablers and barriers has been identified and analyzed in the study.

Afterwards, ISM and TISM approach has been executed for identifying the driving and dependence power for factors, enablers and barriers affecting CMS. Driving factors and enablers have further been analysed by Entropy Approach for identifying the weighatage of the criteria. MOORA technique and VIKOR analysis have been utilized to rank the facilitators. In this framework, suitability index value for different manufacturing system has been calculated by Analytic Hierarchy Process.

The key contibution of this research are as follows:

- It represents existing status of research regarding execution of CMS.
- With the application of Analytic Hierarchy Process suitability index of cellular manufacturing system has been calculated in Indian context.
- ISM model have been developed for factors and barriers of CMS.
- TISM model has been developed for enablers of CMS identifying their mutual contextual and interpretation relationship.

- Weightage of the CMS facilitators has been calculated using Entropy approach.
- Ranking of facilitators has been done using MOORA and VIKOR method

1.11 SUMMARY AND CONCLUSION

The main stress of this research is to provide the subsequent view of the cellular manufacturing system in Indian context. In this research various factors, barriers, and enablers related with the cellular manufacturing system have been deliberated and some gaps regarding these in the hypothetical research have been acquainted.

The way of acceptance and execution of CMS in Indian industry is not an easy task. There are various concerns which deliberately affect the acceptance and execution of CMS. These concerns are factors, enablers, and barriers which are having high relationship to CMS implementation. A number of factors, enablers and barriers have been recognized in the contemporaneous work and effort has been made to evaluate the nature. Suitability index value for the cellular manufacturing system is calculated and compared with other manufacturing methods in Indian industries using analytical hierarchy process.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The current market is very competitive and volatile so that to sustain in this kind of dynamic environment one industry should have sufficient flexibility as well as with economic amount of production. Cellular manufacturing is combination of job shop manufacturing and product manufacturing incorporating group technology. The main aim of cellular manufacturing is to react as fast as possible, by making a broad range of similar kind of products, while making as little as waste as possible. The requirements of customer are changing frequently in nature enforces to make a strong need for a newer technique of manufacturing systems. For getting the adequate competency and to remain in survival with highly dynamic markets, Industries should have minimum flexibility to respond over a range of products to produce on the shop floor. It may concluded, that cellular manufacturing systems are the systems that can be adopted to get the production with economic aspects as well as manufacturing concerns; to ensure the existence in the competitive and dynamic environment. Cellular manufacturing systems (CMSs) are the type of manufacturing system which is used to produce different product families based on similarity of operations in the minimum time with different machine cells based on similar processing at the minimum possible cost without negotiating with the quality of the product. Several studies are devoted to examining the potential benefits of CMS implementation. Some of these research have been studied here as follow as

Sharma et. al., (2018) carried out research to develop an exemplary for the enablers affecting the application of CMS by using ISM technique. The enablers have been found with literature and questionnaire based survey. The ranking of these enablers have been done using the survey. The MICMAC approach is used to derive the related reliance of “dynamic enablers” (i.e., used to derive other enablers) and “reliant enablers” (i.e., used to derived from other enablers). Enabler improved production process stability and capability, increased automation, and improved worker skill flexibility are the driving enabler or the potential enablers of the system. Thus, these enablers may be called as the 'key enablers'. These key enablers will assist the management in synchronizing the various activities in the production system for healthy cellular manufacturing system.

Kumar et. al., (2017) studied that India is struggling potentially to provide challengeable platform for the manufacturing. Global customer’s demands vary with the range of products free from any defect, at lowest possible price. In India industries are showing their interest to transform in lean manufacturing practices to get the customer satisfaction. Industries are adopting lean manufacturing system methodology to enhance respective effectiveness via minimizing scrap within system whereas, in India, lean manufacturing is still found lot of impediments. Therefore, the barriers have to be identified before implementing the lean manufacturing system in India. This research elaborates the ISM technique for the connection between the several barriers affecting lean manufacturing in Indian manufacturing. A model is developed for potential barriers affecting lean manufacturing system. Driving power and dependence power is calculated for the various interrelated barriers. The study provides an organized attitude for abolition of barriers affecting lean implementation with dynamic power and reliance power. The tenacity of this research is to categorize and ranking of the various barriers of lean manufacturing. **Nomden et. al., (2017)** carried out a study to find the applicability of Cellular Manufacturing (CMS) systems in different situations. Cellular manufacturing system finds the suitable position from the past years. Case study of CMS implementations provides the advantages of CMS technique, such as reduction in set-up, arrangement, yank production, etc. But still, reviews specify that complete cellular manufacturing systems are exceptional in exercise. In fact, cellular manufacturing systems are only applicable to a restricted amount. From the past literature, barriers affecting implementation of cellular manufacturing system has not been found. The research customs a challenge to plug this information gap through a numerous case study. In starting, they report to what extent the methods of CM are applicable in a number of non-cellular circumstances. Then secondly, they recognize the barriers and enablers responsible for the success or failure of CM system in these circumstances. Thirdly, they designate promising issues for future research. The subjects of study are Dutch manufacturing companies, which do not, or only partially, apply CM techniques. The examination and consequent analysis of these cases results into the documentation of a number of factors affecting the applicability of cellular manufacturing system. Important are an organization's arsenal of manufacturing technologies, as well as product and demand characteristics. Also the organization of manufacturing and the possibility to exert extensive control over jobs and resources seem important. Some benefits from links between different business functions have also been found. By confronting from findings with the current state of CM research they derive a number of promising directions for further study.

Omrani et. al., (2017) represents a forceful optimization archetypal for capacity condition judgments in a condition of supply chain. Strong optimization narrates to a noticeable area for tackling with optimization difficulties with specific records. The research gives an idea about a strong optimization model is formulated for a supply chain for 3 echelons has been. The initial step is the development of all a integer linear formulation of deterministic mixed model in consideration of a problem associated with supply chain. The main requirement of the model is to determine the hesitations in the coefficients in both the sides with development of complex linear model of vigorous design. A intellectual model is developed to satisfy the rough complement for a considered experiment.

Biswas et. al., (2017) carried out a research to investigate the duties in CSR development using AHP. CSR deployment systems are frequently not enough analyzed, mostly in regard with its stakeholders to get the optimum output. This study is the effort in the field of increasing complex flexibility in context of responsibility of CSR with AHP among the various MCDM techniques. AHP is the appropriate tool to categorize the importance of various available alternatives along with incorporating the benefits of performances; the technique is important when reputational scores are not found in literature. AHP is utilized to inculcate application of CSR.

Selvaraj et. al., (2017) studied that the cutting process of metal relies on the various parameters of machining. This is the study which highlights the application of AHP for getting the best turning parameter of machining with EN25 steel with using coated carbide tool. The parameters of machining in this study are cutting speed, feed rate and depth of cut. This study is synthesized for instantaneously reducing various parameters like surface roughness, micro hardness and maximizing material removal rate (MRR). This study practices a MCDM technique in which firstly weight is calculated and then normalization of parameters is done to get the final rankings of the various parameters. The findings of this study show that the best grouping of machining parameters is essential to increase the machining performance. The method can be used further for finding the best ranking of other machining process with altered processing parameters.

Ilhan et. al., (2016) studied that making a decision is the crucial and most important in real life situation. The decision maker must be reliable, experienced and familiar with the considered elements. Multi criteria decision method (MCDM) approaches can get focus on various possible alternatives. The MCDM techniques that are used maximum are AHP, MOORA, VIKOR and TOPSIS. In this paper, various methods of rankings and their relative merits are elaborated. These methods have been applied to ISE-30 during 2002–2012 in Turkey and found to be most effective. The findings of the study are compared within the terms of the techniques properties and the year-end returns.

Linnala et. al., (2016) stated that multi criteria decision for best solution is a commonly used method in various field of design and manufacturing. These methods can be used to synthesize various contradictory intentions that are normally seen in papermaking organizations. In this research, various procedures of MCDM approaches in papermaking applications are elaborated on the basis of past literature review. Past literature may be classified into parts of production based and technique-based revisions. Though meticulous divorce is challenging because some applications in optimization techniques are very practical but is still developed to suit that nature of complications. Correspondingly, a detailed analyze of an optimization technique itself may be illustrated by using a detailed practical case study. Overall, multi criteria optimization saves cost and uses suitable tool for different purposes in the papermaking organizations. The results are reliable for model-based solution in manufacturing. Therefore, the demonstrating step must follow the phases of the technique. Now in this way the MCDM method can be used further in production sectors.

Upadhye et. al., (2016) seen that various organizations striving hard to remain their selves in dynamic competitive environment. Lean manufacturing system (LMS) is found to be most suitable method of manufacturing to remain in competition by minimizing waste and effective utilization of all available resources. The barriers of Lean Manufacturing System have been recognized for proper handling. An ISM approach is utilized to get the interrelationship between the various barriers. The study identifies the various driving and dependence factor. The lack of top management's commitment and lack of employee involvement barrier founds as most potential barrier as the bottom location of the barrier in the diagraph, results in strong driving power in the implementation of LMS.

Sindhwani et. al., (2016) studied about the investigation of interpretive structural method model for Agile Manufacturing System (AMS). This study initiates with recognition of the factor of AMS. Then after identification various factors are developed in ISM approach to get the dynamic and reliance power. MICMAC method is also discussed to illustrate the importance of factors of AMS.

Onay et. al., (2016) studied that in modern world Globalization is commonly developed over the process of manufacturing. Important indicators for national income and welfare have to be traded off. Trading is dependent on the nature of surrounding. Paper gives a brief idea to develop the Terminology of Units for Territorial Statistics (NUTS) Level 2 regions in Turkey. This study analysis the NUTS Level 2 regions of Turkey and formulated by various techniques like TOPSIS, MOORA and VIKOR approaches with using 10 issues of foreign trade activities. Twenty six NUTS have been identified in Level 2 regions in the Turkey. NUTS are evaluated with 10 standards which are the subjects under the foreign trade activities. Results are given and regions are compared. Study gives a brief idea to use further these MCDM techniques in process industries.

Chand et. al., (2015) Stated that risk is there in each association of supply chain type of manufacturing. The author has practiced the various decision techniques in the nature of supply chain. Corporations have to be careful about the various risks in the nature that can affect the short-term production in supply chain type of manufacturing. The four risk have been identified from the past literature that are transportation risks, operations risks, supplier related risks and market related risks. The study uses the techniques to find the optimal solution among the various available alternatives. MCDM approach ANP and MOORA is used to find the ranking. It also addresses the insinuations for supply chain managers as they balance a concern for risks with their efforts to search for, select, develop, and manage their set of supply chain partners.

Kaur et. al., (2015) stated about the need of quality tool as an important factor in total quality management (TQM) and TPM is synthesized to develop the optimal objectives in business industries. This logical study deals with AHP to get the optimal solution among the various hard alternatives influencing the system. The research involves the various measuring parameters of manufacturing like as productivity, employee competency, quality, cost, flexibility and delivery, employee safety and moral. AHP method is elaborated for the researchers for deep understandings in context of manufacturing in Indian organizations.

Tramarico et. al., (2015) carried out a research to investigate a comparative study used to outline the literature in the research topic. This paper aims to present a bibliometric study of multi-criteria decision-making methods most applied in publications from 1990 to 2014. This study provides relations of papers published in the Web of Science Core Collection, regarding the following keywords: Analytic Hierarchy Process and Supply Chain. The study manifested that the Analytic Hierarchy Process has been the most suitable MCDM technique applied in publications from 1993. Study also illustrates the analysis of the predecessor and successor citation network for the selected publications under topics as supplier selection, supply development, performance measurement and value chain through the Cit Net Explore software.

Jain et. al., (2015) studied that to increase the manufacturing flexibility, manufacturing organizations are looking at flexible manufacturing system (FMS) as a viable alternative to enhance their competitive edge. There are, however, some factors which affect the flexibility of FMS. Fifteen factors are identified from the literature and found their evaluation by interpretive structural modeling (ISM), exploratory factor analysis, confirmatory factor analysis and graph theory matrix approach. But, Interpretation of the mutual relationship of factors is comparatively weak in ISM. Thus, an upgraded version of ISM i.e. Total interpretive structural modeling (TISM) methodology is used to develop the model and the mutual relationship of factors is identified in the TISM. This paper is an application of TISM to interpret the mutual relationship with the ISM using the tool of interpretive matrix and leads to evolving the frame work and find out driving and the dependence power of factors, using fuzzy MICMAC analysis. The result shows that use of reconfigurable machine tool, automation and flexible fixturing have strong driving power and weak dependence power and are at the lowest levels in hierarchy in the TISM model. Hence, superior performance of FMS can be achieved by improving the driving factors of flexibility.

Raja et. al., (2014) Cellular manufacturing is a regimented practice for fulfilling the philosophies of GT in production industries. From the past literature survey the information related with CFP and CLP has scarcity in availability rather than designing of cell. The investigation is related with a heuristic method of matrix formation by analyzing the different cells of intra-cell layout type of production system. The research is helpful for researches doing research in the field of manufacturing. The main target is to develop sequencing and scheduling along with the identification of same processing parts and identical working machines in a cell. The various movements of the product is considered in the study to validate the findings. The findings are validated by comparing them with the available concepts.

Anbumalar et. al., (2014) conducted a case study for implementation of cellular manufacturing system for a process industry. Managers across the country are motivated to maintain the production rate with ever changing demands or continuous modification in the products. Layout is very important in an industry as slight change in the position of machine can greatly influence the rate of production. Layout type also enlightens the flow of material and products. In CMS different cells are designed to investigate the minimum movements of the product to enhance the production and to reduce the floor space requirements by maximum utilization of available resources in context of Indian industries. The cell consists of machines with identical processing and parts those are matching in operations. Line layout, U layout, and multi layout is explained in the research in which machines can be organized according to sequence of operations, in line, U shape, and Multi-row machines. The findings of the study suggest the conclusion of case study investigated for particular case of production. The result provides the best possible layout for CMS by bearing in mind various arrangement of possible layouts with an target to get the better control over production and to reduce the total cost of manufacturing by synthesizing the alternative routings of parts in the organization by investigating the ARENA software to get the better result and for proper validation of the existing system.

Jain et. al., (2014) researches the evaluation of the most appropriate flexibility in the manufacturing sector is one of the strategic issues that may affect the flexible manufacturing system (FMS). In this paper, a multiple attribute decision making method methodology is structured to resolve this problem. The two decision making methods, which are analytic hierarchy process (AHP) and compromise solution method, also known as the VIšekriterijumsko KOmpromisno Rangiranje (VIKOR) method, are integrated in order to make the best use of information available. The purpose of using AHP is to turn over the weights of the variable and the VIKOR method is allowed to rank flexibility in FMS. Furthermore, the method uses fuzzy logic to alter the qualitative attributes into the quantitative attributes. Fifteen factors are taken for the evaluation of 15 flexibilities. In this paper, we concluded that production flexibility has the most impact in 15 flexibilities and programme flexibility has the least impact in these 15 flexibilities by this methodology.

Malhotra (2014) reveals that in today’s volatile market, which is influenced by global competition and changing customers’ demands, has made the manufacturing companies to look for new manufacturing systems which can fulfil their requirements for global competition. Reconfigurable manufacturing systems (RMSs) are those systems which are capable to meet the requirements of modern manufacturing industries. But adoption and implementation of RMSs is not an easy task. There are certain barriers which not only influence the implementation process but also influence each other. The main objective of this paper is to identify and analyze these barriers. In the present work, these barriers have been identified through the literature, their ranking is done by a questionnaire-based survey and interpretive structural modelling (ISM) approach has been utilized in analyzing their mutual interaction.

Jain et. al., (2014) said that productivity has often been cited as a key factor in a flexible manufacturing system (FMS) performance, and actions to increase it are said to improve profitability and the wage earning capacity of employees. Improving productivity is seen as a key issue for survival and success in the long term of a manufacturing system. The purpose of this paper is to make a model and analysis of the productivity variables of FMS. This study was performed by different approaches viz. interpretive structural modelling (ISM), structural equation modelling (SEM), graph theory and matrix approach (GTMA) and across-sectional survey within manufacturing firms in India. ISM has been used to develop a model of productivity variables, and then it has been analyzed. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are powerful statistical techniques. CFA is carried by SEM.EFA is applied to extract the factors in FMS by the statistical package for social sciences (SPSS 20) software and confirming these factors by CFA through analysis of moment structures (AMOS 20) software. The twenty productivity variables are identified through literature and four factors extracted, which involves the productivity of FMS. The four factors are people, quality, machine and flexibility. SEM using AMOS 20 was used to perform the first order four-factor structures. GTMA is a multiple attribute decision making (MADM) methodology used to find intensity/quantification of productivity variables in an organization. The FMS productivity index has purposed to intensify the factors which affect FMS

Arora et. al., (2013) proved that Cellular manufacturing system is playing a vital approach for batch and job shop production systems. Group technology has been an essential tool for developing a cellular manufacturing system. This paper elaborates various cell formation techniques and highlights the significant research work done in past over the years and attempts to points out the gap in research.

Sundharam et. al., (2013) have investigated an AHP methodology to get the workable development of production organizations in Indian context. The AHP technique is synthesized with various possible attributes and sub attributes. The method is relied on the decision of the experts. The judgments can be conflicting towards the particular criteria. Kumar and Kumar (2013) have investigated an integrated method of AHP-TOPSIS in the area of telecom service providers (TSPs) to get the benefits of quality performance of relative service in Delhi. The findings of the survey will help the various service providers in context of technical and service performance to the standard and take corrective actions to cultivate the challenges in nature.

Dixit et. al., (2013) carried out a case study in Indian industries to investigate the various elements that affects the application of CMS. The research deals with the identification of various elements like factors, enablers and barriers that affects the application of considered manufacturing system. The various issues related with the manufacturing system provide the substantial knowledge to the researchers to investigate in the field of cellular manufacturing system.

Kumar et. al., (2013) identified18 variables affecting the lean Manufacturing System while investigating Indian industry with questionnaire survey. Lean Manufacturing improves the quality at various stages in the production along with the reduction in cost and production time. An ISM approach is utilized to categorize the various elements after recognition of each and every variable by a survey in some automobile industry in India. Circumstantial relationship between the recognized variables is done by ISM technique. 9 elements fall in relent quadrant and 9 variables are found as the dynamic factors affecting LMS. Relative cost benefits and top management commitment variables are recognized as potential factors and founds in the bottom of the hierarchy.

Attri et. al., (2013) gives an idea about ISM technique which is a practice that gives interactions between the elements affecting the system that establish delinquency associated with the system and aids in developing the circumstantial affiliation between the available considered elements of the system that explains the subjects. This technique has been significantly used widely to investigate the various links between the considered factors associated with the system. ISM methodology develops with the documentation of elements, identified from the literature or questionnaire survey. After this step a contextual relationship is established among the various elements of the system. After contextual relationship, a SSIM is established depends upon judgment of elements. Then, SSIM is transformed into RM and transitivity is developed. Once transitivity has done, a mathematical model is developed. After SSIM diagraph is developed and model is framed with partitioning of the elements for managerial implications. The findings of the research are useful to understand the basics of the technique.

Chang et. al., (2013) investigated to identify part families and machine cells for minimizing intercellular movement and for maximum utilization of machines with in cell. There is no literature found in the past for simultaneous consideration of three critical issues in the cellular manufacturing system design process. The critical issues are cell development, cell arrangement and intra-cell machine routings. The research provides a two-stage mathematical indoctrination model is formulated to investigate the three serious matters with the deliberation of substitute process routings, operation arrangements, and fabrication capacity. Then after, because of the combinatorial nature of the above model, a well-organized tabu search algorithm based on a generalized correspondence coefficient is proposed. Computational results from test glitches enlightens that their planned model and solution method are effective and efficient.

Jain et. al., (2013) investigated that the flexibility in manufacturing system is required so it is called flexible manufacturing system (FMS), but in FMS, there is different flexibility, which is incorporated. So, in manufacturing system which flexibility has more impact and which is less impact in FMS is decided by combined multiple attribute decision making method, which are analytic hierarchy process (AHP),technique for order preference by similarity to ideal situation, and improved preference ranking organization method for enrichment evaluations. The criteria weights are calculated by using the AHP. Furthermore, the method uses fuzzy logic to convert the qualitative attributes into the quantitative attributes. In this paper, a multiple attribute decision making method is structured to solve this problem and concluded that production flexibility has the most impact, and programme flexibility has the least impact in FMS based on factors, which affect the flexibility in FMS by using combined multiple attribute decision making method.

Pasupuleti et. al., (2012) conducted a study that after strategy of cellular manufacturing system, arrangement of works is necessary for the routine manufacturing. In cellular manufacturing system scheduling is usually convoluted. The research provides an approach for ranking the parts, as well as formulating the total schedules in a cellular manufacturing system. The processing sequences of the jobs and routings with lead time are developed in the study. The system gives a strategy for different dispatching rules such as first come first serve, shortest processing time, longest processing time, earliest due date and least slack. Various performance measures like the make span, mean flow time, mean lateness and mean tardiness are used to evaluate the considered dispatching rules. Study provides the sequence of parts to process on each machine and the total schedules for all the operations of the parts. A practical example is discussed for the better understanding of the research.

Sushil (2012) investigated that Interpretive structural modeling (ISM) is a process that transforms unclear and poorly articulated mental models of systems into visible, well-defined models useful for many purposes. The interpretation of links is comparatively weak in ISM; the interpretation of the directed link in terms of how it operates is lacking. This paper is an attempt to interpret the links in the interpretive structural models using the tool of Interpretive Matrix and leads to evolve the framework and methodology of total interpretive structural modeling (TISM). First, an overview of ISM is provided. This is taken-up further by highlighting the need of interpretation of interpretive structural models. In order to evolve the framework of TISM, the tool of Interpretive Matrix is briefly introduced, which is integrated into the methodology of TISM. The basic process of TISM is presented in a step-by-step manner with indicative directions for scaling-up this process. Some tests for validating total interpretive structural models are also proposed. Finally, the basic process of TISM is illustrated with the help of an example in the context of organizational change. This process can be used for conceptualization and theory building in organizational research.

Ngampak et. al., (2011) Carried out the research for selection of facilities layout design based on systematic layout by AHP technique. A case study is conducted on Electronic Manufacturing Service (EMS) plant. Functional type of layout was followed by the manufacturing plant that was not found suitable due to the nature of an EMS that has high-volume and high variety environment. Moreover, quick response and high flexibility was also needed. Then, cellular manufacturing system layout design was exercised for the selected family of products. Various techniques have been used to find the possible cellular layouts for the organization. In order to evaluate the best alternative layout, criteria for plant selection were determined. These performance measures were weighted by AHP. Then, the best cellular layout design was selected. This case study enlightens the gap for design and selection of the best Electronic Manufacturing Service layout.

Sharma et. al., (2010) Studied the just in time manufacturing to obtain the optimal solution in Indian manufacturing industries. Due to the dynamic environment and changing needs of customer their remains a competitive environment among the manufacturing industries. In context of surviving one has to continuously upgrade itself with promising result to the customers. Organizations has to work in the area of reduction of various factors like work in process inventory, set up time, and increase in rates of production. The research uses the AHP as an MCDM method to investigate the JIT technology.

Raj et. al., (2009) carried out the research to realize Manufacturing companies about the importance of flexible manufacturing systems (FMS) due to continuous changing demands of the customer and growing international competition. Implementation of FMS application is typical to adopt initially. The research synthesizes and analyze the barriers of FMS. A questionnaire based survey was conducted to rank these barriers. Based on the survey, Interpretive Structural Modelling (ISM) method was used for finding the key barriers and their managerial implications.

Grewal et. al., (2008) stated that the Different management and academicians have studied about organization’s competitive advantage stems from its ability to identify, concentrate on and develop its core competencies and activities, and outsource anything which is unrealistic. Outsourcing of logistics systems can contribute to profits by enabling users to maximize financial benefits, focus on core competencies, reduce risk and liability, provide wider coverage and flexible capacity, provide dedicated resources, *etc*. In this paper, a decision-making model has been developed using the Analytic Hierarchy Process (AHP) for outsourcing the logistics system. With this technique, several options are considered in the decision analysis that make it possible to adequately evaluate and determine whether outsourcing the logistics distribution may be beneficial or not for the company. The example given in the study proves that AHP can be used effectively to analyze the outsourcing decision for logistics distribution. It is expected to provide practitioners with the systematic analysis needed to make this important decision.

Vaidya et. al., (2004) Carried out a research to present a literature review of the applications of Analytic Hierarchy Process (AHP). AHP is a multiple criteria decision-making criterion that has been used for various kind of decision-making. This study covers a select few, which could be of wide interest to the researchers and practitioners. The study analyses some of the papers published in international journals, and gives a brief idea about many of the referred publications. Papers are assorted according to the themes identified, and on the basis of the areas of application. A total of 150 application papers are referred to in this study, 27 of them are critically analyzed.

Bayazit (2004) gives a good knowledge of Analytic hierarchy process which is a multi-criterion decision technique. This paper investigates on evaluating flexible manufacturing system in a tractor manufacturing company. Sensitivity analysis has been also done for testing the real outcome of the model. Factors and their relative importance have been identified and it is found that the final outcome remains stable in all cases when the weights of the main criteria affecting the decision were varied up and down by 5 percent in all possible combinations. The limitation found during the study is that analytic network process is more appropriate methodology when there are dependencies and interactions among the criteria in a decision-making model because AHP technique based on linear independence of criteria and alternatives.

CHAPTER 3

SURVEY BASED ON QUESIONNAIRE

3.1 INTRODUCTION

The chapter of the study characterizes the organization and conclusions of survey based on questionnaire in the area of cellular manufacturing system. The main aim of the research is to elaborate the factors, enablers and obstacles which affect the performance parameters of cellular manufacturing system. Several criteria's are considered to get the deep understandings in this survey. Some physiognomies such as development of questionnaire and the organization related with questionnaire are demonstrated in this chapter.

3.2 CONSTRUCTION OF QUESTIONNAIRE

The survey based on questionnaire was circulated to illustrate different factors, enablers and barriers for the implementation of cellular manufacturing system. The literature review available for cellular manufacturing system was synthesized to get the formulation of the questionnaire. Some academician and industry experts are also contacted in the area of cellular manufacturing system to get the relevant results, while formulation of the questionnaire. The feedback from surveys was not up to the mark and some respondent are busy enough to provide the time to fill the questionnaire. Thus, the survey based on questionnaire was deliberated in a manner that very less time is required to fill the questionnaire.

The survey of questionnaires was formulated in two halves. Firstly the Section A characterizes the industry silhouette like total employees in numbers; turnover of the plant, parts manufactured in the plant etc. is involved in this section. Section B comprises the issues related with the cellular manufacturing system designed to calculate the weightage of factors, enablers and barriers affecting the cellular manufacturing system. The importance weightage is calculated in five points Likert scale from 1-5. The questionnaire developed was as per the literature available in the past related about the cellular manufacturing system and is developed with one to five points on Likert scale. In likert scale the ranking has to be done in between one to five scale where five is the top most ranking means that it is highly influencing factor, barrier or enabler on the other hand one point can be assigned to a less affecting criteria. Mostly the questionnaire is distributed in the organization at my own level with personal and professional level, some of questionnaires are e-mailed and uploaded on Google drive to obtain a sufficient large sample. Some questionnaires, along with covering letter, self-addressed, were mailed to the officials of the organizations. There was total 150 questionnaires developed at my end and then after they were circulated in the organizations. Only 110 questionnaires are received back, out of which 20 questionnaires were found incompletely filled and hence 90 questionnaires are considered useful for the research work.

3.3 QUESTIONNAIRE DEVELOPMENT

3.3.1 Industries Targeted

The survey is conducted on the Indian industries working in the different sectors like production industries, metal industries; fabrication and sheet metal industries; automotive industries, plastic industries etc. are considered.

3.3.2Organization of Questionnaire

The personal level self-contacting, e-mails and postal survey methods were used for the completion of the above said task. The official executives/managing directors/general managers/managers/senior managers are in most cases communicated for obtaining their feedbacks. Some of these questionnaires are e-mailed to some officials of the organizations and some questionnaires, along with a covering letter, self-addressed, were mailed to these top level managers. In majority of cases the questionnaires were filled by authorities like senior executive and some were filled by the others on behalf of concerned related official.

3.4 RESULT OF SURVEY

There was 150 questionnaires sent to the Indian organizations and Academicians for filling the issues related with cellular manufacturing system survey; from those 110 questionnaire were acknowledged back additionally again out of 110 questionnaire 20 questionnaire forms were found incompletely filled were rejected for more assessment. After collection of rightly filled forums 90 questionnaires are synthesized to get work with them that means reaction rate is 47.36 percent. Depending on the responses of the survey; section A profile of company data of 90 respondents are characterized in table 3.1. Section B of the questionnaire survey which represents the factors, enablers and barriers affecting the cellular manufacturing system on five point Likert scale are represented as per appendix-1.

Table 3.1: Assemblage of Data from industries

Sr. No.	**Explanation**	**Variety**	**Industries (out of 90)**
I	Working Staff (In numbers)	<100	27
		Bet. 101-500	25
		Bet. 501-1000	18
		>1000	20
II	Annual Turnover (In Cr.)	<10	18
		Bet. 10-50	22
		Bet. 50-100	20
		>100	30
III	Number of different production department	Single	11
		Bet. 2-3	26
		Bet. 4-6	32
		>10	21
IV	Number of Parts manufactured in the plant	<20	24
		Bet. 20-50	36
		Bet. 50-100	18
		>100	12
		<10	19

V	Level of Productivity in terms of units per man per day (approx.)	Bet. 10-25	28
		Bet. 25-50	22
		> 50-100	21

3.5 RESULTS FROM THE INDUSTRIES

3.5.1 Personnel in the Industries

It is observed that 27 out of 90 industries shows that 30% industries have less than 100 employees. And 25 out of 90 industries become 28% industries employee’s ranges between 101-500. Afterwards 18 out of 90 industries about 20% and 20 out of 90 nearly 22% industries have employees between 501-1000 and more than 1000 respectively as shown in figure 3.1.

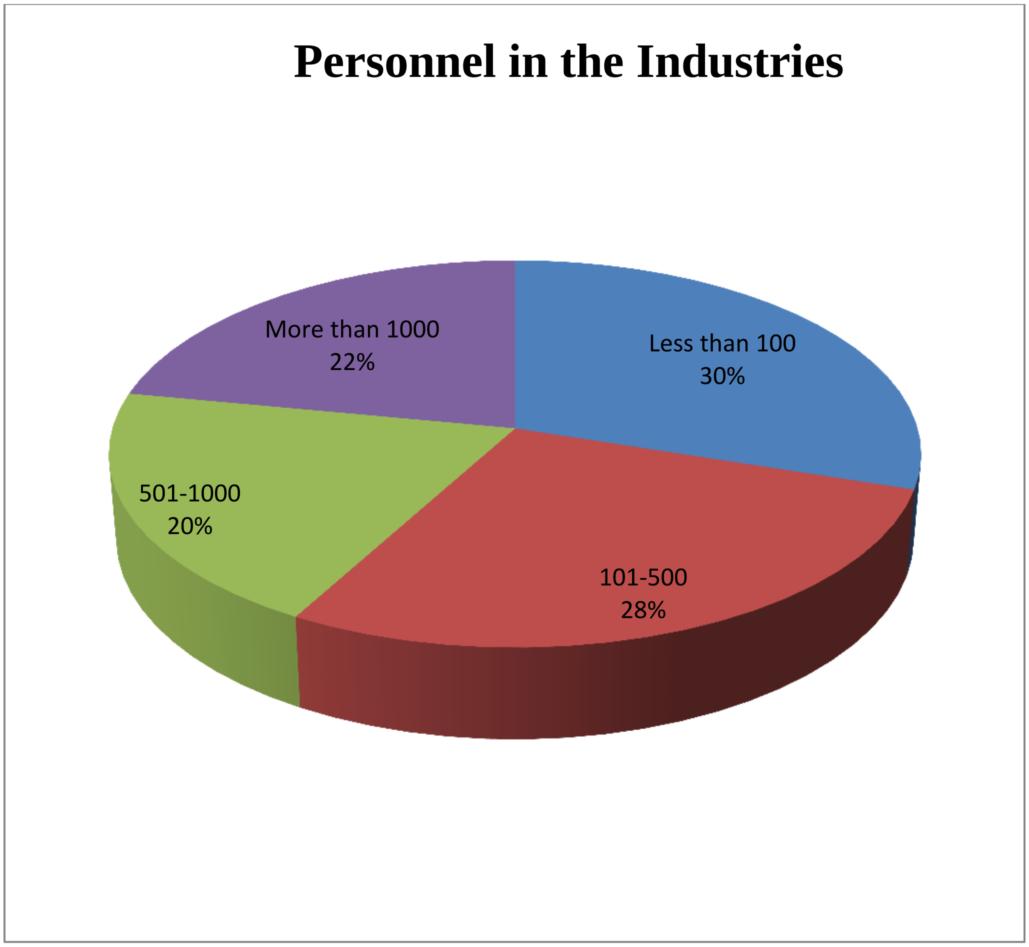

Figure 3.1: Personnel in the Industries

3.5.2 Annual Turnover of the Industries

It is found that turnover of organization from 90 industries, 30 out of 90 which is 33% of situations attain more than 500 Cr. Turnovers and 22 out of 90 nearly 25% industries have turnover ranges in 10-50 Cr. 20 out of 90 about 22% industries have turnover fall in 50-100 Cr. 18 out of 90 industries means 20% industries are lie in less than 10 Cr. Turnover category as shown in figure 3.2.

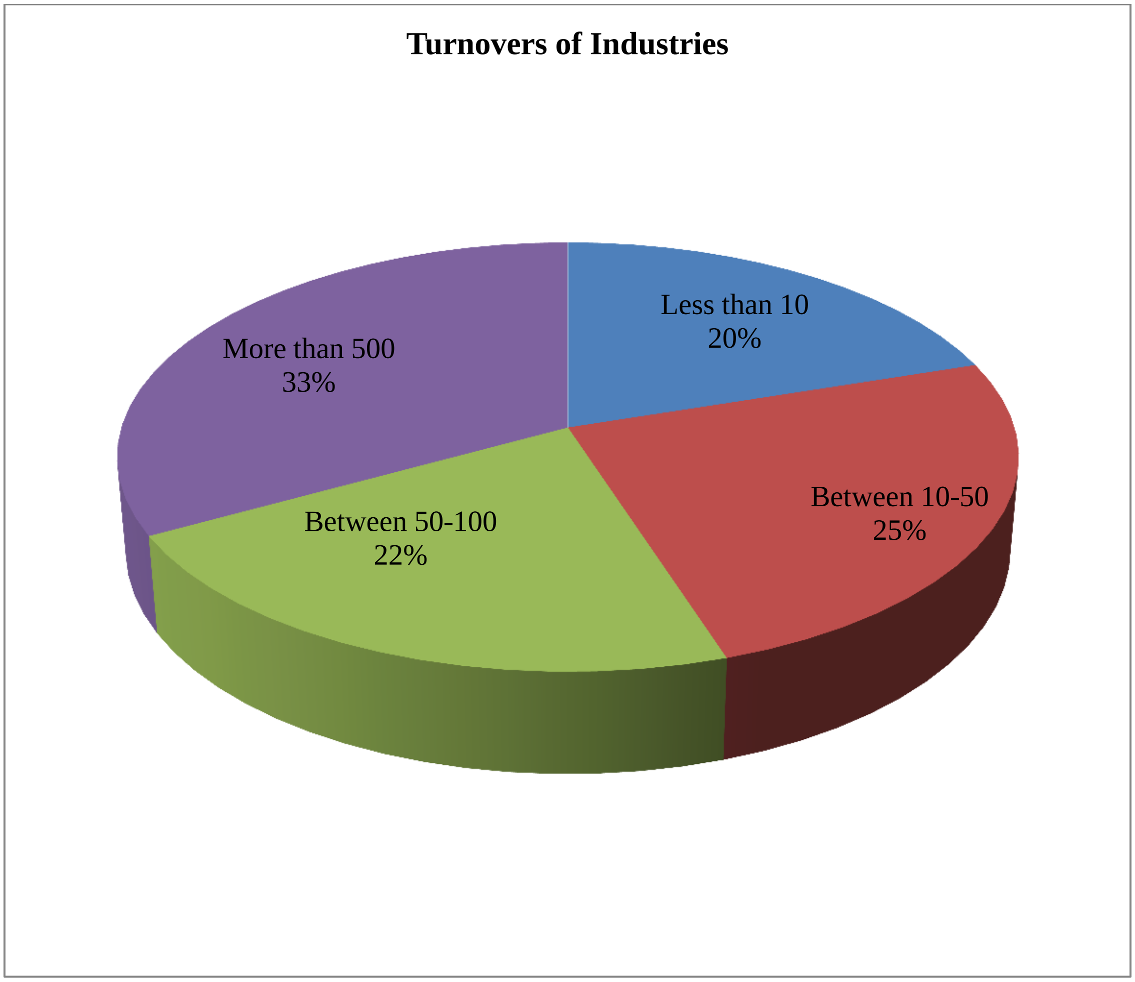

Figure 3.2: Annual Turnover of Industries

3.5.3 Production Departments in the industries

It is found that production departments in the industries 32 out of 90 about 36% have between 6-10 departments. And 26 out 90 about 29% companies have between 2-3 departments. 21 out of 90 about in 23 % of cases they have more than 10 department. 11 out of 90 are only 12% situations get single department as shown in figure 3.3.

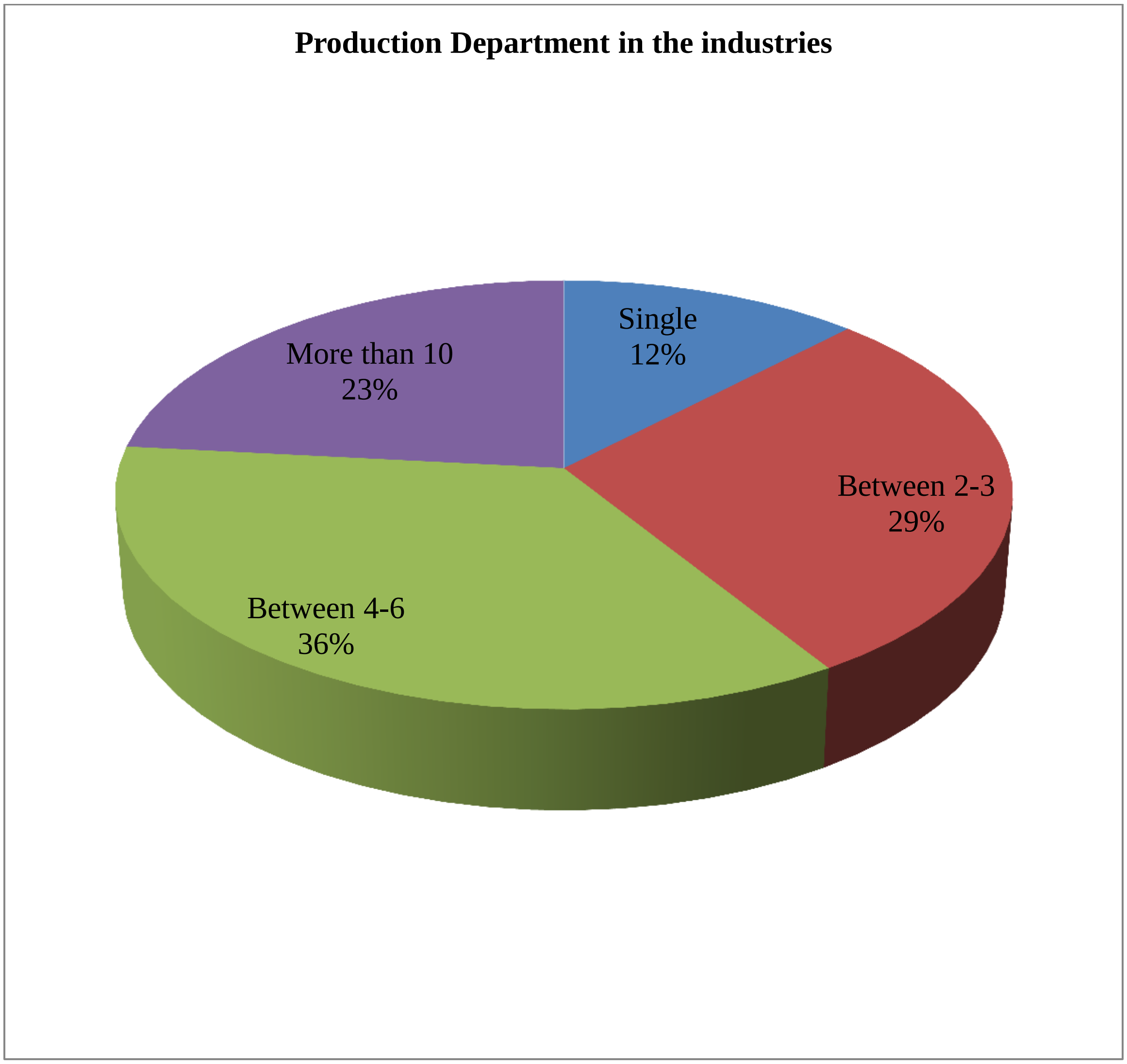

Figure 3.3 Production departments in an Organization

3.5.4 Parts produced in the Industries

The number of Parts manufactured in an organization found that 36 out of 90 about 40% industries are developing in range 20-50 in numbers of components. And 24 out of 90 about 26% industries are generating less than 20 numbers of parts in organizations. 18 out of 90 means 20% industries are manufacturing fall in 50-100 numbers of components. 12 out of 90 near about 13% are manufacturing more than 100 components as shown in figure 3.4.

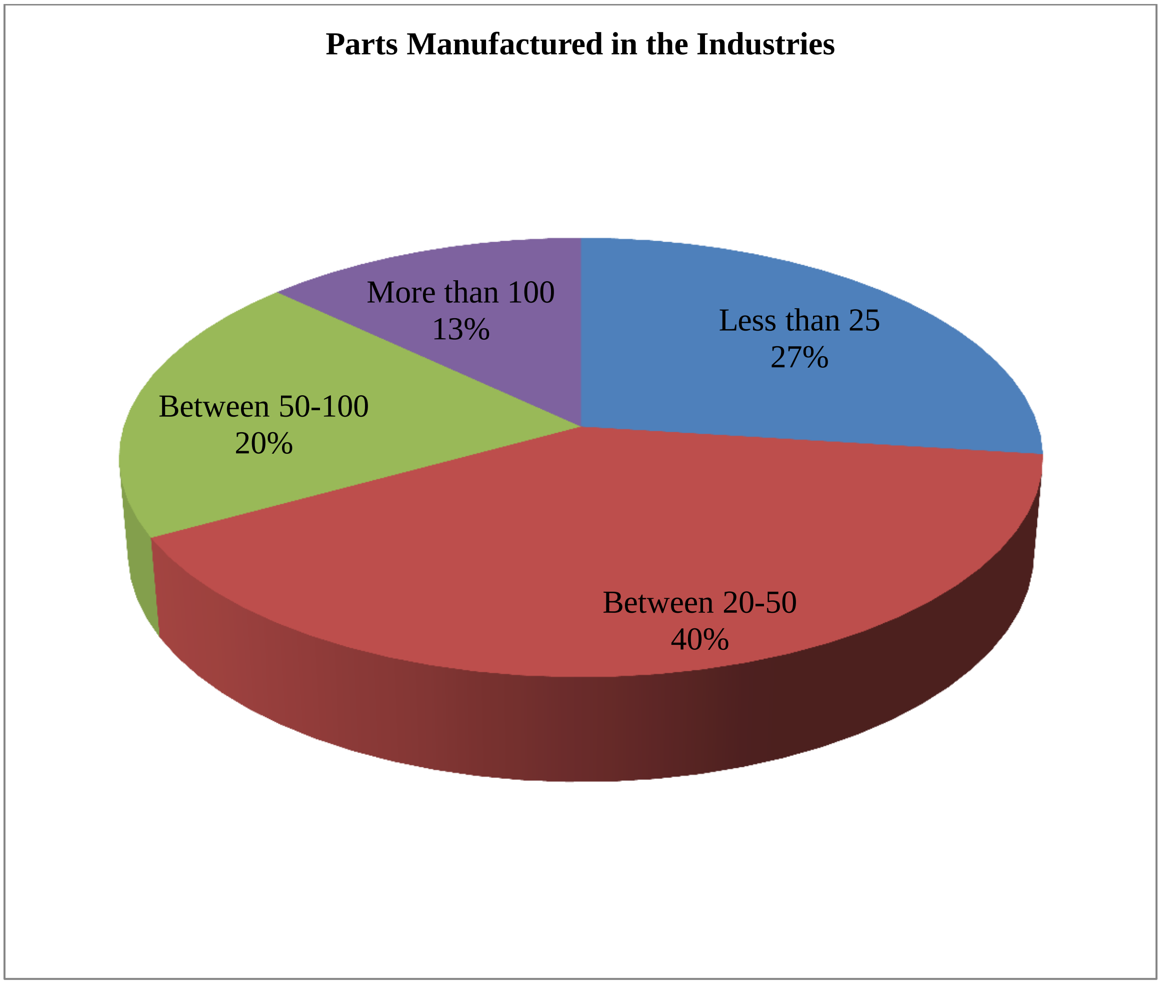

Figure 3.4: Parts manufactured in the Industries

3.5.5 Level of Productivity

It is found in the survey that 28 out of 90 samples imply that 31% industries fall in between 10-25. Afterwards 22 out of 90 nearly about 25% industries have productivity level range in 25-50. 21 out of 90 means around 23% samples have range of 50 to 100 and 19 out of 90 nearly around 21% industries have productivity less than 10 as presented in figure 3.5.

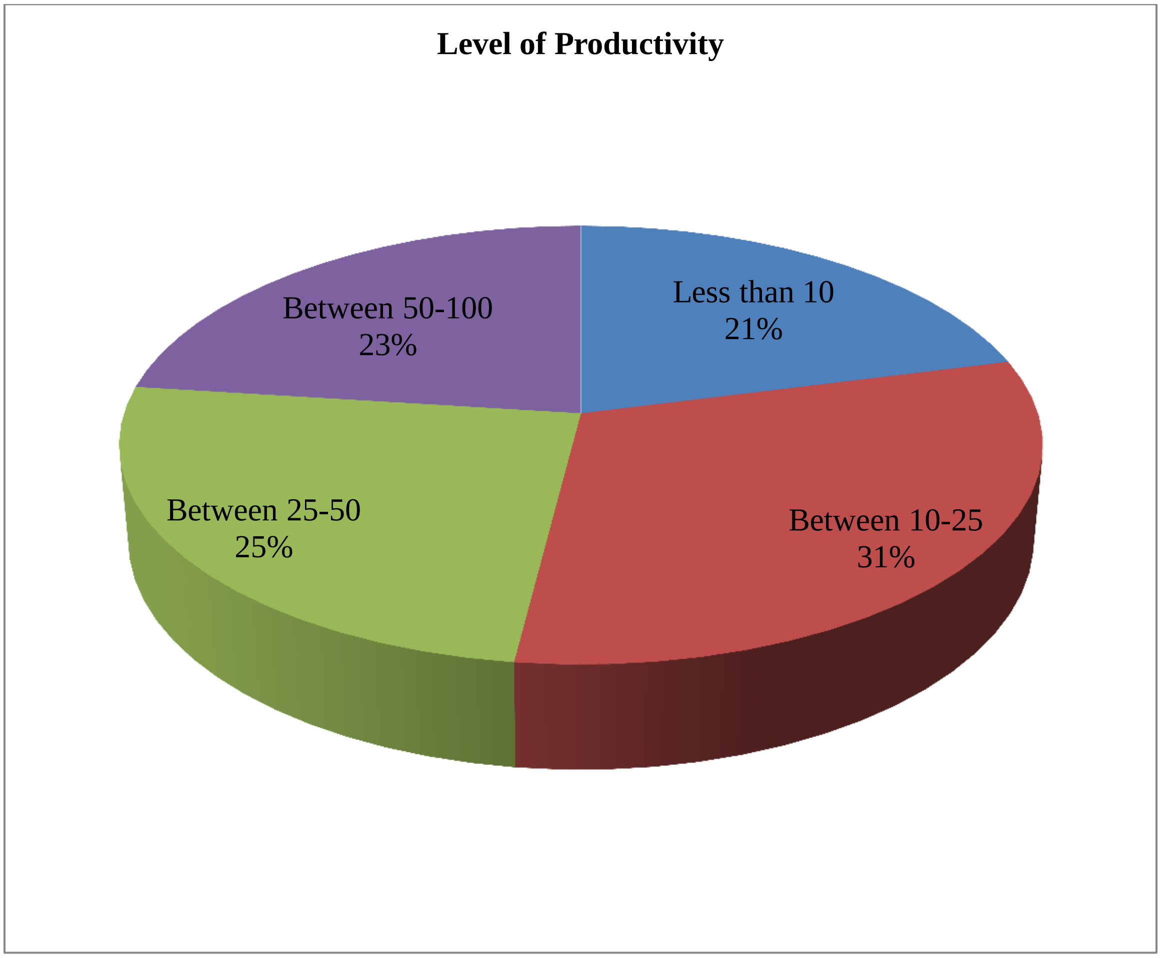

Figure 3.5: level of Productivity

3.6 CONCLUSIONS

It is found from the survey of 90 industries related about the various factors, enablers and barriers affecting cellular manufacturing system are as follows

1. The 90 industries are divided in 5areas*i.e.*staff; annual turnover; production department; parts developed; level of productivity.
2. Survey of 90 samples concludes that, 30% respondents have less than 100 workers; 34% respondents have more than 500Cr turnovers; 35% organizations are having 6-10 departments; 40% organizations are generating 20-50 number of parts in an industry and 31% organizations have level of productivity range in 10-25.

CHAPTER 4

VALIDATION THROUGH ANOVA ANALYSIS

4.1 INTRODUCTION

Analysis of variance is a technique which is used to validate the results acquired from the survey conducted on the cellular manufacturing system. It is used to deal with the importance between the two separate samples (Kothari, 2004). This technique aids in implementing this test and it acts as a significant instrument of examination for the researchers. This method will help in determining that weather the data collected is from people having the same mean. One-way ANOVA is generally used to find out the substantial difference between the mean values (or levels) of the parameters, for the case in which similar observations are recorded. 'Substantial' states to the practical range of means that would not normally arise from the chance deviation within groups.

The ANOVA analysis is a basic procedure for checking the difference between disparate groups of annals for comparison(Kothari, 2004). "The ANOVA analysis is the total amount of dissimilarity in a set of data is characterized into two types, the amount which can be attributed to chance and the amount which can be attributed to specified causes" (Kothari, 2004; Christensen, 2011). Then in last the result is examined by F-Test and it is derived by given below formula.

$$\text{F-ratio} = \frac{Mean\ Square\ between\ samples\ variance}{Mean\ Square\ within\ samples\ variance}$$

Now, calculated F-value is compared with standard F-limit executed for known Degree of Freedom (DOF). Now if calculated F-value is same or more than the F-limit value (which is defined differ for different significant level value) then we can conclude that the difference between the data is significant (Stoline, 1981).

4.2 OUTLINE OF ANOVA ANALYSIS

The data collected from 90 Indian companies is examined with the help of ANOVA analysis. One way ANOVA analysis was used for validating the data. ANOVA method synthesizes the numerous possible types of samples that can follow within that element. After that the differences within the factor has been analyzed. This method considers the following steps (Kothari, 2004):

(i) Find out the mean of each sample i.e. calculate

$\bar{Y}1$, $\bar{Y}2$, $\bar{Y}3$, $\bar{Y}4$… $\bar{Y}$k 1)

Where there are k samples.

(ii) Work out the mean of the sample means as follows:

$$\bar{\bar{Y}} = \frac{\overline{y_1} + \overline{y_2} + \overline{y_3} + \cdots \ldots\ldots\ldots, \overline{y_k}}{\text{No.of samples (k)}} \quad 2)$$

(iii) Consider the above deviances of the sample mean from the sample means and find out the square of such deviances of the sample (and SS between). Representatively, this may be derived as:

$$SS \text{ bet.} = n_1\left(\bar{Y}1 - \bar{\bar{Y}}\right)^2 + n_2\left(\bar{Y}2 - \bar{\bar{Y}}\right)^2 + \ldots\ldots. + n_k\left(\bar{Y}k - \bar{\bar{Y}}\right)^2 \quad 3)$$

(iv) Now divide the result obtained from equation (iii) by the degree of freedom between the samples to obtain variance or mean square (MS) between samples. Representatively, this can be written as:

$$\text{MS between} = \frac{SSbetween}{(k-1)} \quad 4)$$

Where (k-1) represents degree of freedom (d.f) between samples.

(v) Then we will work out to calculate the sum of squares within (or SS within), Symbolically this can be written as:

$$\text{SS within} = \sum(Y_{1i} - \overline{Y_1})^2 + \sum(Y_{2i} - \overline{Y_2})^2 + \ldots\ldots.. + \sum\left(Y_{ki} - \bar{\bar{Y_k}}\right)^2 \quad 5)$$

i = 1, 2, 3…

(vi) Divide the result of (v) step by the degree of freedom within samples to obtain the variance or mean square (MS) within samples. Symbolically this can be written as:

$$\text{MS within} = \frac{SSwithin}{(n-k)} \qquad 6)$$

Where (n-k) represents degree of freedom within samples.

n= total number of items in all the samples i.e. n1+n2+……. +nk.

K=number of samples.

(vii) For a check, the sum of squares of deviations for total variance can also be worked out by adding the squares of deviations when the deviations for the individual items in all the samples have been taken from the mean of the sample means. Symbolically, this can be written:

$$\text{SS for total variance} = \sum\left(Yij - \bar{\bar{Y}}\right)^2 \qquad 7)$$

i = 1, 2, 3…

j = 1, 2, 3…

This total variance must be equal to the total of the result obtained from the equation (iii) and (v) i.e.

SS for total variance= SS between + SS within

The degree of freedom for total variance would be equal to the number of elements in all samples minus one i.e., (n-1). The degree of freedom for between and within must add up to degree of freedom for total variance i.e.

$$(n-1) = (k-1) + (n-k) \qquad 8)$$

This fact explains the additive property of the ANOVA technique.

(viii) Finally, F-ratio may be worked out as under:

$$\text{F-ratio} = \frac{MSbetween}{MSwithin} \qquad 9)$$

This ratio is generally used for judging the difference between several means is significant or a sampling fluctuation. This can be noted from the table, giving the value of F for given degree of freedom at different levels of significance. If F value is less than the prescribed value in the table then the difference is taken as insignificant i.e. due to chance and the null hypothesis of no difference between sample means stands. When the value of F comes greater than or equal to the value of F prescribed in the table then the difference is considered as significant (which means the samples could not have come from the same universe) and accordingly the conclusion may be drawn.

4.3 ORGANIZATION OF ANOVA

This part of chapter describes the procedure to validate the data composed from questionnaire survey of 90 organizations.

Step 1: Calculation of mean

In this method compute the mean and variance for the data with using equation 1) and 2) as shown in table 4.1

Step 2: SS between and MS between

After calculation of mean and variance sum of squares between the samples is formulated by using equation 3) and 4) and then mean of squares between the samples using equation 4) as shown in table 4.2

Table 4.2: F-critical value at 0.10, 0.05, 0.01 significant factor

Source of Variation	SS	MS	F	F crit. (for*0.10*)	F crit.(for*0.05*)	F crit. (for*0.01*)
Between Groups	325.32	3.65	1.698	1.3004	1.4013	1.6041
Within Groups	2018.52	2.151				
Total	2343.84					

Step 3: Compute the SS within and MS within

Sum of square within and Mean square within can be calculated by equation 5) and 6). This is as depicted in table 4.2

Step 4: Analyze F- Ratio

F- ration is obtained by dividing MS between by MS within.

Step 5: Comparison of F-value

F- ration is equated by the standard F- critical value for 0.01, 0.05, and 0.10 as depicted in table 4.2.

It is found that our derived F- ratio is more than F- critical value at all stages for 0.01, 0.05, and 0.10. Thus the questionnaire is validated for further use.

4.4 CONCLUSION

Data has been verified at different levels by ANOVA analysis as per table 4.2. After ANOVA analysis implemented on data collected from questionnaire survey, the calculated F- value is 1.698 as shown in table 4.2. Afterwards; this result has been compared with 0.01, 0.05 and 0.10 levels. Achieved F-value is 1.698 which found to be higher than the F-value 1.6041 (at 0.01 significant factor), F-critical value 1.4013 (at 0.05 significant factor) and F critical value 1.3004 (at 0.10 significant factor). This result validates that our data collected from questionnaire survey is substantial.

CHAPTER 5

MODELLING FOR CMS BARRIERS BY ISM APPROACH

5.1 INTRODUCTION

The customers' requirements are flexible in nature those not only differs in volumes, high level of quality with reasonable cost and continuously updated models, but also new selections to outfit various palates (Carvalho et. al., 2011). This kind of flexible nature of end users is giving thrust to new pioneering products and services even without vacillating to pay high cost.

Cellular manufacturing system transformation from conventional manufacturing system is a hard fact in the literature. Certain barriers always remain as threats towards the implementation of cellular manufacturing system (Irani et. al., 1999). The main challenge is related with the implementation of cellular manufacturing system. The literature of barriers in implementation of cellular manufacturing system is rare forcing the researchers to investigate on the identification and treatment with relationship of these barriers. In this chapter 14 barriers have been identified as key barrier which affects the implementation process of cellular manufacturing system.

5.2 Barriers of Cellular Manufacturing System in Indian industries

The potential barrier affecting of cellular manufacturing system may be categorized as operational barrier, human linked barrier and official barrier (Meredith 1987, and Beatty et. al., 1990). The operational barrier is associated with internal infrastructure and explanation hitches; human linked barrier exhibits uncertainty like workers resistances and official barrier is the manufacturing incompatibility. In this chapter the respondent were asked to rate the problem encounter (or hope they may encounter) in implementing CM system in their firm (Table 5.1).

These were asked to rate the problems on five point likert scale (very low, low, moderate, high and very high). The Factory floor layout (mean=3.38) is the most prominent barrier in the implementation of Cellular Manufacturing system in the Indian Industries. Lack of advanced machinery is also identified as the potential obstacle (Adler et. al., 1988).

Table 5.1 obstacles in transformation to CMS

S. No.	Barriers/obstacles in transformation to CMS	Mean Score	Rank
1.	Factory floor layout	3.38	1
2.	Lack of advanced machinery	3.36	2
3.	Material transportation problems	3.20	3
4.	Lack of funds	3.10	4
5.	Manufacturing Process	3.07	5
6.	Other external forces	3.04	6
7.	Management obstacle	3.02	7
8.	Workers resistance	2.92	8
9.	Lack of Training	2.81	9
10	Lack of knowledge about GT	2.76	10
11.	Lack of support from various departments	2.70	11
12.	Influence of trade unions	2.62	12
13.	Communication barriers with suppliers	2.51	13
14.	Legislation, regulation and policies of government	2.50	14

5.3 ISM MODELLING

Interpretive structural modelling is a best method to find the optimal solution and it always remains in quite interest of researchers to find out the solution and relationship among variables. But the presence of large number of elements tends to accentuate the condition which is then in turn aggravated by the complex inter-relationship among those elements (Raj et al., 2009). Basically, the technique comprises to various elements affecting the system, associating those factors in a demarcated dualistic situation, building a RM model from the judgments and categorized digraphs are developed. All the elements have a direct or indirect dependency over the manufacturing system supporting a complex system. There are various methods found in the literature but ISM approach is the most suitable approach to get the relationship. ISM approach assists the society of researchers in developing their cooperative information and demonstrating various linkages and dependencies in such a way to increase the capability to understand its convolution. The originator of this approach was the Warfield who has used this approach first ever to construct a model for multi oriented alternatives. The technique categorizes the arrangement of the system for various factors and delivers a chance to analyze it with altered perceptions. This approach is targeted towards a better understanding of the conflicting objectives. It is a strong interface for commanding order and trend on the relationships between the elements of a system, to establish a ladder of actions needed to get the perspective aim of effective organization (Benjaafar et. al., 2010).

5.3.1 ISM METHODOLOGY

ISM is an approach that is the important and crucial for developing a circumstantial relationship between the different barriers constructing the system (Jain and Raj 2015). It is interpretive structural modelling to get the relationship between the variables after scrutiny by the judgements of the groups (Singh et. al., 2011). It has two properties which separates it from others is its simplicity and efficiency in terms to save time and to get the optimal result.

The basic step in ISM is to obtain the interrelated elements constructing and affecting the system (Mittal and Sangwan 2011). Then second step after this is to construct a circumstantial relationship between them and charted into a Structural Self Interaction Matrix (SSIM). After developing the SSIM model, Reachability Matrix (RM) has to be established and subjected to check for the transitivity. Depending on the interrelationship exhibited by RM all the transitive linking is removed and directed diagraph is obtained made. Then the diagraph is developed into ISM Model with factors nodes replaced by statements (Raj et. al., 2008). The last and final stem is to investigate the ISM technique in respect of theoretical inconsistent and obligatory changes are presented. The procedure is as shown in figure 5.1.

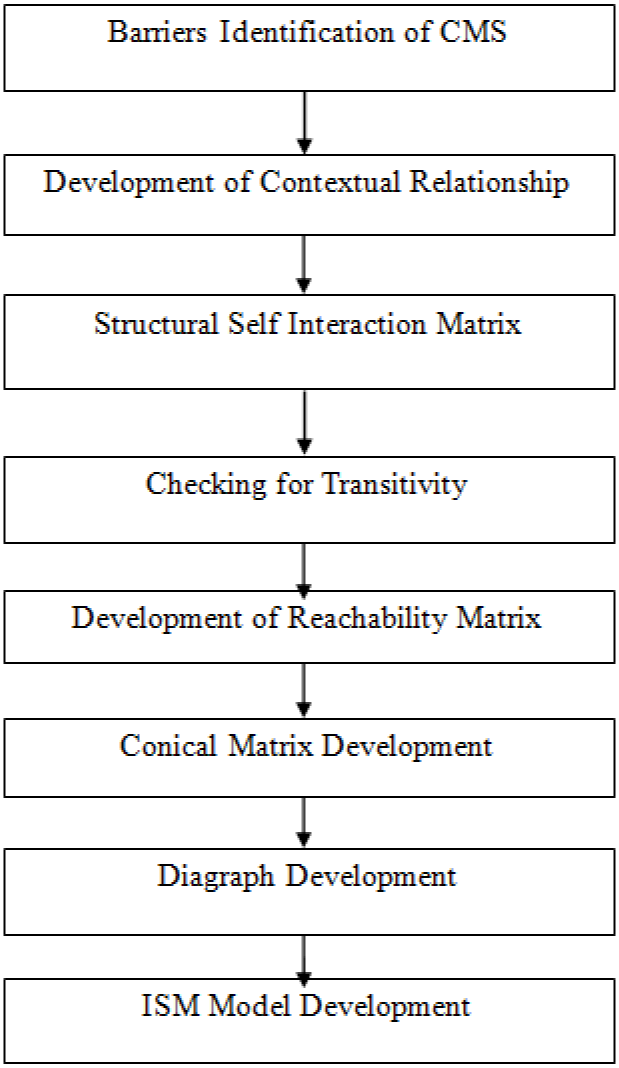

Figure 5.1: Modeling barriers with ISM approach

5.3.2 Benefits of ISM

The merits of the ISM technique are elaborated in a classified manner Mittal and Sangwan (2014) the advantages of this methodology are as follows:

- Order and implementation with direction to relate multifaceted relationship prevailing among different barriers affecting the system.
- Important understandings within the barriers and their inter-relationship.
- Helps in generation of an organized model
- Easy analysis and aids in identifying the beleaguered areas where technique can be synthesized to get the result.

- Aids in suitability of elements by strengthening the interrelationship among the various elements.

5.4 EXAMINATION OF CMS BARRIERS

The examination, consist of various steps, are demonstrated here as follows

Step 1: Barrier disturbing organization

The barriers influencing the organization have identified with past literature review and with the suggestions from academic world and engineering professionals as deliberated in chapter 3 are shown in Table 5.2.

Table 5.2: Barriers affecting CMS

Sr. No.	**Barriers affecting CMS**
1	Factory floor layout
2	Lack of advanced machinery
3	Material transportation problems
4	Lack of funds
5	Manufacturing Process
6	Other external forces
7	Management obstacle
8	Workers resistance
9	Lack of Training
10	Lack of knowledge about GT
11	Lack of support from various departments

12	Influence of trade unions
13	Communication barriers with suppliers
14	Legislation, regulation and policies of government

Step 2: Enlargement of SSIM

For constructing SSIM, the basic4representationsare used to indicate the inter-relationship between the barriers (*i* and *j*)

- *V* defines that barrier *i* will disturb the barrier *j*
- *A* defines that barrier *j* will disturb the barrier *i*
- *X* defines that barrier *i* and *j* will disturb each other
- *O* defines that barrier *i* and *j* are insulated.

Based on the suitable inter-relationship between barriers, the construction of SSIM is done. For constructing this SSIM table, these barriers relationship was particularized in between the experts of industry and academia as shown in table 5.3.

Table 5.3 SSIM

Barriers	14	13	12	11	10	9	8	7	6	5	4	3	2
1	A	V	O	A	O	O	A	O	V	A	A	V	O
2	O	V	O	X	O	V	V	A	V	V	A	V	
3	O	V	O	A	O	O	A	O	O	A	V		
4	A	V	O	A	O	O	A	V	V	V			
5	A	V	O	A	V	O	V	O	V				
6	A	V	O	A	O	O	A	O					
7	A	V	V	A	V	O	V						
8	A	V	V	A	A	A							
9	O	V	V	A	A								
10	O	V	O	A									
11	V	V	O										
12	O	V											
13	A												

In developing the barriers in SSIM step, the four representations are synthesized to illustrate the inter-relationship between barrier (i and j)

- Symbol *V* is owed to cell (2, 13) because barrier 2 inspires barrier 13
- Symbol *A* is owed to cell (4, 11) because barrier 11 inspires the barrier 4
- Symbol *X* is owed to cell (2, 11) because barriers 2 and 11 inspires each other
- Symbol *O* is owed to cell (12, 14) because barriers 12 and 14 are insulated.

Step 3: Development of RM

The reachability matrix is acquired from SSIM. The reachability matrix specifies the inter-relationship amongst barriers in the binary system. The different connections between barriers represented by symbols *V*, *A*, *X*, *O* used previously in SSIM are replaced by binary numbers of 0 and 1. The succeeding steps are used to substitute *V*, *A*, *X*, and *O* of SSIM to get RM.

- the (*i*, *j*) article in the SSIM is *V*, then the (*i*, *j*) admittance in the RM grows 1 and the (*j*, *i*) admittance matures 0
- the (*i*, *j*) article in the SSIM is *A*, then the (*i*, *j*) admittance in the RM matures 0 and the (*j*, *i*) admittance matures 1.
- the (*i*, *j*) article in the SSIM is *X*, then the (*i*, *j*) admittance in the RM matures 1 and the (*j*, *i*) admittance matures 1.
- the (*i*, *j*) article in the SSIM is *O*, then the (*i*, *j*) admittance in the RM matures 0 and the (*j*, *i*) admittance corresponding matures 0.

The RM now momentous is approved as initial RM which is shown in Table 5.4.

Table 5.4 Initial RM

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	0	1	0	0	1	0	0	0	0	0	0	1	0
2	0	1	1	0	1	1	0	1	1	0	1	0	1	0
3	0	0	1	1	0	0	0	0	0	0	0	0	1	0
4	1	1	0	1	1	1	1	0	0	0	0	0	1	0
5	1	0	1	0	1	1	0	1	0	1	0	0	1	0
6	0	0	0	0	0	1	0	0	0	0	0	0	1	0
7	0	1	0	0	0	0	1	1	0	1	0	1	1	0
8	1	0	1	1	0	1	0	1	0	0	0	1	1	0
9	0	0	0	0	0	0	0	1	1	0	0	1	1	0
10	0	0	0	0	0	0	0	1	1	1	0	0	1	0
11	1	1	1	1	1	1	1	1	1	1	1	0	1	1
12	0	0	0	0	0	0	0	0	0	0	0	1	1	0
13	0	0	0	0	0	0	0	0	0	0	0	0	1	0
14	1	0	0	1	1	1	1	1	0	0	1	0	1	1

- For (2,13) admittance in the SSIM is *V*, hereafter the (*i*,*j*) admittance in the RM develops 1and the (*j*, *i*) admittance develops 0
- For (4,11) admittance in the SSIM is *A*, hereafter the (*i*, *j*) admittance in the RM develops 0 and the (*j*, *i*) admittance develops 1
- For (2,11) admittance in the SSIM is *X*, here after the (*i*, *j*) admittance in the RM develops 1 and the (*j*, *i*) admittance develops 1
- For (12,14) admittance in the SSIM is *O*, hereafter the (*i*, *j*) admittance in the RM develops 0 and the (*j*, *i*) admittance also develops 0.

Final reachability is acquired by including the transitivity. If the relation is there between three elements and inter-relationship holds between the A and B and relationship also holds between the B and C then in turn inter-relationship between A and C will also be held. Transitivity is notified as 1* and it is represented in final RM. Final reachability matrix is presented in Table 5.5

Table 5.5 Final RM

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	0	1	0	0	1	0	0	0	0	0	0	1	0
2	0	1	1	0	1	1	0	1	1	0	1	0	1	0
3	0	0	1	1	0	0	0	0	0	0	0	0	1	0
4	1	1	0	1	1	1	1	0	0	0	0	0	1	0
5	1	0	1	1*	1	1	0	1	0	1	0	0	1	0
6	0	0	0	0	0	1	0	0	0	0	0	0	1	0
7	0	1	0	1*	0	0	1	1	0	1	0	1	1	1*
8	1	0	1	1	0	1	0	1	0	0	0	1	1	0
9	0	0	0	0	0	0	0	1	1	0	0	1	1	0
10	0	0	0	0	0	0	0	1	1	1	0	0	1	0
11	1	1	1	1	1	1	1	1	1	1	1	1*	1	1
12	0	0	0	0	0	1*	0	0	0	0	0	1	1	0
13	0	0	0	1*	0	0	0	0	0	0	0	0	1	0
14	1	0	0	1	1	1	1	1	0	0	1	0	1	1

Step 4: Partitioning of the RM

The reachability and predecessor set is developed for every barrier can be seen in final RM. The RM involves the constituent its element and the other components in this it may aid to accomplish, however the forerunner set involves of the constituent itself and the other components that can support in accomplishing it. The crossing of arrays is derived for all the barriers. The barriers may fall in highest flat in the ISM ladder. The top most barriers in the grading may not benefit to succeed any other component beyond its position in the grading. The higher barriers are firstly recognized and then divided out from the other barriers. Then, his procedure is executed a number of times till up to find out the barriers in the next level. This process is sustained until or unless the level of each barrier to be identified. Then afterword's these stages help us to construct a diagraph .In this chapter, the fourteen barriers are depicted in Tables 5.5–5.13. as in the final RM it was concluded that barrier 1 disturb the barriers 1,3,6,13 (see straight parallel in the row) come in the classification of RM set and barriers 1,4,5,8,11,14 (see straight vertically in the column) come in the group of forerunner set.

The intersection set can be dogged by judgement amongst reachability and forerunner set. The barrier which is available in reachability, antecedent and intersection set are come in the classification of level I, II, III, IV, V,VI,VII,VIII, and IX. The barrier which are in group of class that cannot be considered in next iteration. Level partitioning process of these barriers is completed in nine iterations as shown in Tables 5.6–5.14.

.

Table 5.6 Iteration level of barriers 1

B	R S	AS	IS	Level
1	1,3,6,13	1,4,5,8,11,14	1	
2	2,3,5,6,8,9,11,13	2,4,7,11	2,11	
3	3,4,13	1,2,3,5,8 ,11	3	
4	1,2,4,5,6,7,13	3,4,5,7,8,11,13,14	4,5,7,13	
5	1,3,4,5,6,8,10,13	2,4,5,11,14	4,5	
6	6,13	1,2,4,5,6,8,11,12,14	6	
7	2,4,7,8,10,12,13,14	4,7,11,14	7,14	
8	1,3,4,6,8,12,13	2,5,7,8,9,10,11,14	8	
9	8,9,12,13	2,9,10,11	9	
10	8,9,10,13	5,7,10,11	10	
11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	2,11,14	2,11,14	
12	6,12,13	7,8,9,11,1	12	
13	4,13	1,2,3,4,5,6,7,8,9,10,11,12,13,14	4,13	I
14	1,4,5,6,7,8,11,13,14	7,11,14	7,11,14	

Table 5.7 Iteration level of barriers 2

B	R S	AS	IS	Level
1	1,3,6	1,5,8,11,14	1	
2	2,3,5,6,8,9,11	2,4,7,11	2,11	
3	3,	1,2,3,5,8 ,11	3	II
4	1,2,5,6,7	3,4,5,7,8,11,14	5,7	
5	1,3,5,6,8,10	2,5,11,14	5	
6	6	1,2,5,6,8,11,12,14	6	II
7	2,7,8,10,12,14	7,11,14	7,14	
8	1,3,6,8,12	2,5,7,8,9,10,11,14	8	
9	8,9,12	2,9,10,11	9	
10	8,9,10	5,7,10,11	10	
11	1,2,3,5,6,7,8,9,10,11,12,14	2,11,14	2,11,14	
12	6,12	7,8,9,11,12	12	
14	1,5,6,7,8,11,14	7,11,14	7,11,14	

Table 5.8 Iteration level of barriers 3

B	R S	AS	IS	Level
1	1	1,5,8,11,14	1	III
2	2,5,8,9,11	2,4,7,11	2,11	
4	1,2,5,7	4,5,7,8,11,14	5,7	
5	1,5,8,10	2,5,11,14	5	
7	2,7,8,10,12,14	7,11,14	7,14	
8	1,8,12	2,5,7,8,9,10,11,14	8	
9	8,9,12	2,9,10,11	9	
10	8,9,10	5,7,10,11	10	
11	1,2,5,7,8,9,10,11,12,14	2,11,14	2,11,14	
12	12	7,8,9,11,12	12	III
14	1,5,7,8,11,14	7,11,14	7,11,14	

Table 5.9 Iteration level of barriers 4

B	R S	AS	IS	Level
2	2,5,8,9,11	2,4,7,11	2,11	
4	2,5,7	4,5,7,8,11,14	5,7	
5	5,8,10	2,5,11,14	5	
7	2,7,8,10,14	7,11,14	7,14	
8	8	2,5,7,8,9,10,11,14	8	IV
9	8,9	2,9,10,11	9	
10	8,9,10	5,7,10,11	10	
11	2,5,7,8,9,10,11,14	2,11,14	2,11,14	
14	5,7,8,11,14	7,11,14	7,11,14	

Table 5.10 Iteration level of barriers 5

B	R S	AS	IS	Level
2	2,5,9,11	2,4,7,11	2,11	
4	2,5,7	4,5,7,11,14	5,7	
5	5,10	2,5,11,14	5	
7	2,7,10,14	7,11,14	7,14	
9	9	2,9,10,11	9	V
10	9,10	5,7,10,11	10	
11	2,5,7,9,10,11,14	2,11,14	2,11,14	
14	5,7,11,14	7,11,14	7,11,14	

Table 5.11 Iteration level of barriers 6

B	R S	AS	IS	Level
2	2,5,11	2,4,7,11	2,11	
4	2,5,7	4,5,7,11,14	5,7	
5	5,10	2,5,11,14	5	
7	2,7,10,14	7,11,14	7,14	
10	10	5,7,10,11	10	VI
11	2,5,7,10,11,14	2,11,14	2,11,14	
14	5,7,11,14	7,11,14	7,11,14	

Table 5.12 Iteration level of barriers 7

B	R S	AS	IS	Level
2	2,5,11	2,4,7,11	2,11	
4	2,5,7	4,5,7,11,14	5,7	
5	5	2,5,11,14	5	VII
7	2,7,14	7,11,14	7,14	
11	2,5,7,11,14	2,11,14	2,11,14	
14	5,7,11,14	7,11,14	7,11,14	

Table 5.13 Iteration level of barriers 8

B	R S	AS	IS	Level
2	2,11	2,4,7,11	2,11	VIII
4	2,7	4,7,11,14	5,7	
7	2,7,14	7,11,14	7,14	
11	2,7,11,14	2,11,14	2,11,14	VIII
14	7,11,14	7,11,14	7,11,14	VIII

Table 5.14 Iteration level of barriers 9

B	R S	AS	IS	Level
4	7	4,7,11	7	IX
7	7	7,11	7	IX

Step 5: Development of CM

The conical matrix is then constructed by banging collected barriers in the identical levels, through rows and columns of the final reachability matrix. The drive power of a barrier is plagiaristic by adding the numeral of ones in the rows and its dependence power by adding the figure of ones in the columns. Subsequent, drive power and dependence power grades are designed by benevolent upper most ranks to the barrier that have the supreme quantity of ones in the rows and columns correspondingly as shown in Table 5.15

Table 5.15 Conical matrix for barriers

Barriers	13	6	4	8	1	3	5	12	2	7	9	10	11	14	Driver power
6	1	1	0	0	1	1	0	0	0	0	0	0	0	0	2
13	1	1	0	1	0	1	1	0	1	0	1	0	1	0	2
3	1	0	1	0	0	1	0	0	0	0	0	0	0	0	3
12	1	1	1	0	1	0	1	0	1	1	0	0	0	0	3
1	1	1	1*	1	1	1	1	0	0	0	0	1	0	0	4
9	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4
10	1	0	1*	1	0	0	0	1	1	1	0	1	0	1*	4
4	1	1	1	1	1	1	0	1	0	0	0	0	0	0	7
8	1	0	0	1	0	0	0	1	0	0	1	0	0	0	7
2	1	0	0	1	0	0	0	0	0	0	1	1	0	0	8
5	1	1	1	1	1	1	1	1*	1	1	1	1	1	1	8
7	1	1*	0	0	0	0	0	1	0	0	0	0	0	0	8
14	1	0	1*	0	0	0	0	0	0	0	0	0	0	0	9
11	1	1	1	1	1	0	1	0	0	1	0	0	1	1	14
Dependence	14	9	8	8	6	6	5	5	4	4	4	4	3	3	

Step 6: Development of digraph

According to the iteration process and from conical matrix, the digraph comprising transitive links is achieved. After eliminating the unintended links, a final digraph has been constructed. In this expansion, the top level barriers are kept at the top of the hierarchy and second level barriers are placed next to them in hierarchy and so on, till the bottom level is placed at the lowest position in the digraph.

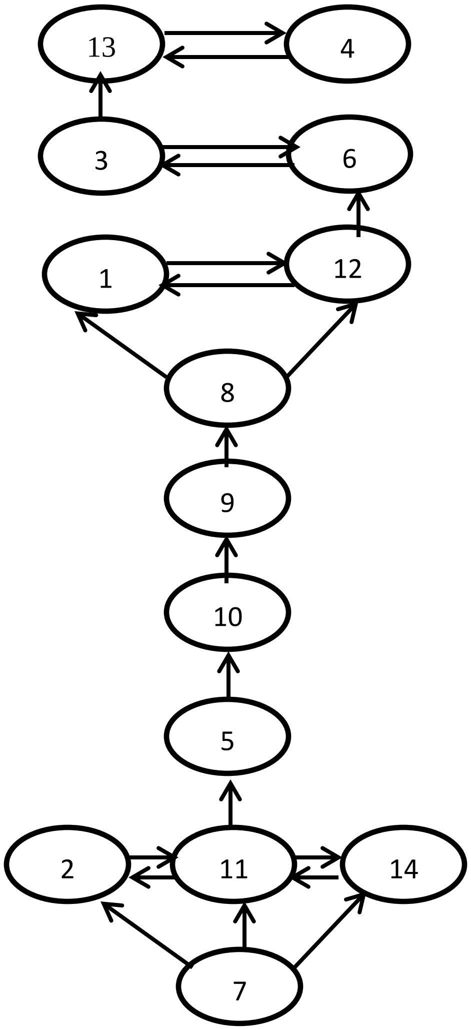

Figure 5.2 Digraph of levels of CMS barriers

Step 7: ISM model

Afterward diagraph development stage diagraph is transformed in to an ISM model by supplanting nodes of the fundamentals with barriers as presented in Figure 5.3.

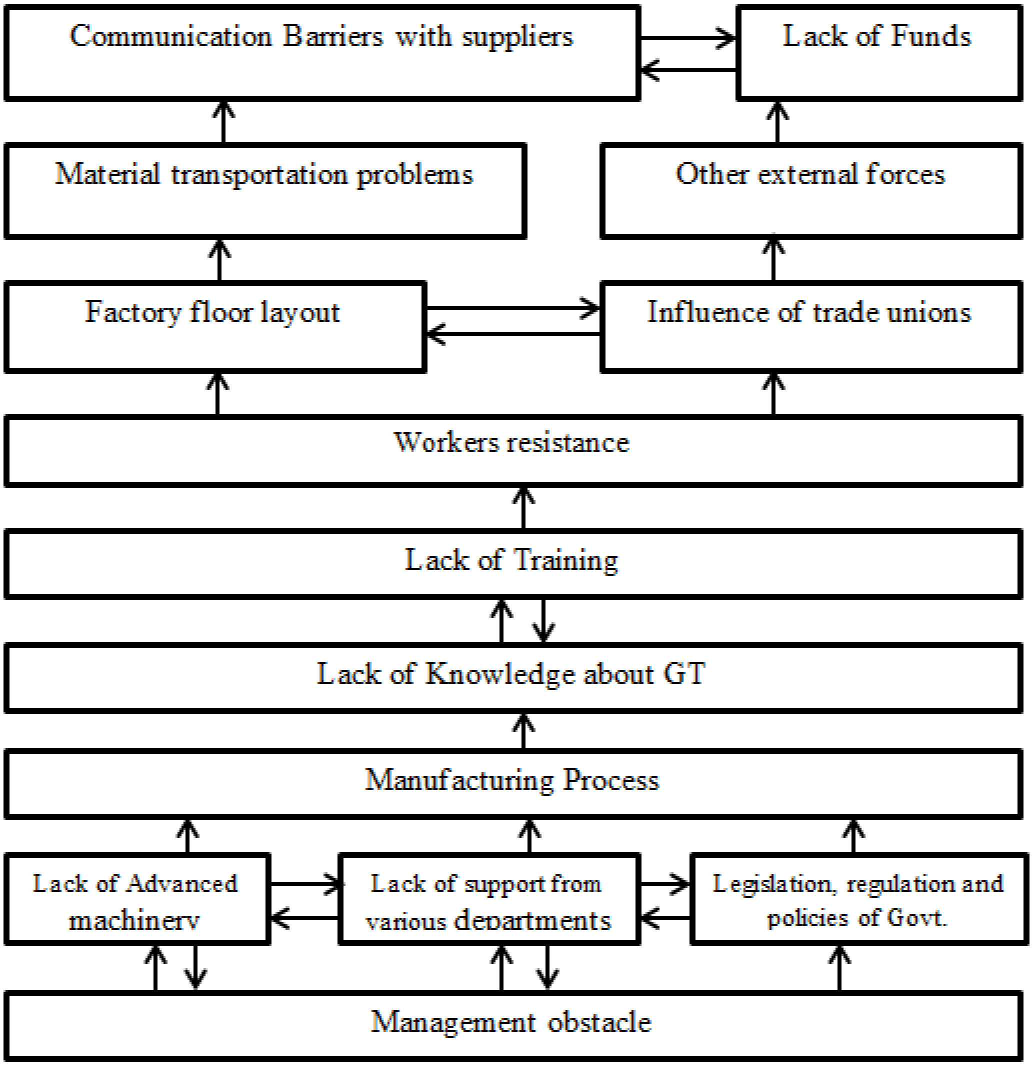

Figure 5.3 Interpretive structural model for CMS barriers

ISM model of CMS barriers have been presented in Fig. 5.3 exposes that the lack of funds and management obstacle in organizations are high driving power barriers in implementation of CMS. An understanding of the ISM model directs that barrier 13 (Communication barriers with suppliers 13) is the highest barrier and barrier 6 (Other external forces) and barrier 3(Material transportation problems) are second highest barrier and barrier 12 (Influence of trade unions) and barrier 1(Factory floor layout) are the third highest barriers in the hierarchy. These are being influenced by lower level barriers. The barriers from fourth level to seventh level (i.e 8,9,10,5) barrier are the central level barriers that affect the fruitful process and administration of CMS. Barrier 2 (Lack of advanced machinery) and barrier 11 (Lack of support from various departments) and barrier 14 (Legislation, regulation and policies of government) are low level barriers.

Barrier 7 have uppermost drive power and lowest reliance; hence, it remains at the bottom of the pyramid. This finding suggest that the difficulty of interfaces of different constituents used in the design of CMS play a significant role and work as the main driving force in the design and implementation of CMS.

Step 8: Check for conceptual inconsistency

The ISM model established in Step 8studied to check for theoretical discrepancy and compulsory amendments are made Figure 5.4 shows that dependence and driving power of the barrier in the categorized manner as follow:

- Cluster 1: Autonomous cluster
- Cluster 2: Dependent cluster
- Cluster 3: Linkage cluster
- Cluster 4: Driving cluster

Cluster 1: Autonomous cluster - five barriers which are development of Factory floor layout (barrier 1), Material transportation problems (barrier 3), Lack of advanced machinery (barrier 2), Manufacturing Process (barrier 5), and Influence of trade unions (barrier 12) are the independent barriers (cluster I). They have poor driving control as well as dependence. They show moderately low substantial role in changeover to CMS.

Cluster 2: Reliant cluster - Dependent barriers are Lack of funds (barrier 4), other external forces (barrier 6), and Workers resistance (barrier 8), and Communication barriers with suppliers (barrier 13). These barriers are poor drivers but sturdily rely on each other. So, the officials must take attention to look after these barriers.

Cluster 3: Linkage cluster - No barrier has been found in this cluster this cluster has a high driving power as well as dependence. But in this research no barrier fall in this cluster out of 14 selected barriers.

Cluster 4: Driving cluster - Five barriers such as Lack of knowledge about GT (barrier 10), Management obstacle (barrier 7), Lack of Training (barrier 9), Lack of support from various departments (barrier 11) and Legislation, regulation and policies of government (barrier 14) are self-governing barriers they have high driving power and poor dependency on other barriers.

Driving Power

14			14											
13														
12														
11					**IV**					**III**				
10														
9			11											
8				9,7,10										
7				2	12									
6														
5					**I**					**II**				
4					5	3								
3						1		4,8						
2									6					13
1														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Dependence

Figure 5.4 Driving power and dependence diagram

5.5 CONCLUSION

The ISM results provide strategic insight also. It is also observed from the Figure 5.3 that Lack of funds and management obstacle for big changes is at the extremity of ISM model entailing high driving power of this barrier. So, the management of companies should. Since this barrier drives all other barriers, a management obstacle will lead to a total collapse of CMS transformation. This study has strong implications for researchers as well as manufacturing managers. The researchers may be stimulated to recognize some other concerns, which may be substantial in addressing these barriers. The manufacturing executives can get a perception of these barriers and comprehend their relative importance and interdependencies and try to overcome these barriers in a successful conversion to CMS.

CHAPTER 6

ANALYSIS OF CELLULAR MANUFACTURING SYSTEM FACTORS BY MICMAC ANALYSIS

6.1 INTRODUCTION

Cellular manufacturing system is a concept of utilizing the benefits of both process type of layout and product type of layout. In cellular manufacturing system machines are grouped into machine cells with similar in type of operation and parts are classified into part family by segregating similar processing. The cells are designed in such a way that the flexibility and productivity level of system are maintained up to the level. The floor space in this type of manufacturing system utilizes the minimum possible area and the machines are closed to each other results in to minimum movements of materials within the machine. Generally the cells layouts are circular in nature that ensures the effective control over the entire process. The inventory as well as setup time is also minimum for the cellular manufacturing system. Cellular manufacturing system regulates the quality standards as per meet of customer satisfaction. A better employee coordination and satisfaction is obtained throughout the process to remain in competitive production (Black et. al., 1991).

The modern customers demand not only varieties, high degree of quality and low price, but also new varieties to suit different tastes (Carvalho et. al., 2011). This implies that modern customers are demanding new innovative products and services even without hesitating to pay high prices. The continuous changing demands of the customers forces the organizations to modify the old manufacturing systems into smart manufacturing system. It is a challenge to the organizations to transform into the newer manufacturing system without compromising with the quality of the product (Sindhwani et. al., 2015).

Cellular manufacturing system is the best manufacturing system in terms of flexibility along with the adequate level of production. But adoption of cellular manufacturing system to change over already existed manufacturing system is not an easy task it need a careful study and knowledge of various elements affecting the cellular manufacturing system (Dixit et. al., 2013).

In this chapter, there are 18 factors are found with a survey that is based on the questionnaire and from the opinions of the experts in the related field. A survey was conducted based on the questionnaire to accumulate the findings from experienced and practical users to know the factors that affects the Cellular Manufacturing System. There are 18 factors were identified and filled on Likerts scale through this survey and then factors of cellular manufacturing system are studied by ISM technique using MICMAC approach. MICMAC is one of the best methods used for calculating the driving and dependence power of the above said 18 factors. The main aim of this study is to elaborate the intensity of factors in terms of driving and driven power and the relationship of various factors among each other.

The purpose of this chapter is to find:

- Orders and ranking of various factors affecting CMS.
- To develop a model between various factors affecting CMS.
- Using MICMAC approach the derive and dependence power of factors.
- Managerial insinuation and conclusion of the study.

The flow diagram of modelling with MICMAC analysis is depicted below in figure 6.1. The factors identified from the literature review has been circulated via questionnaire survey and after compilation of data the formulated with mean score of various factors is presented in table 6.1.

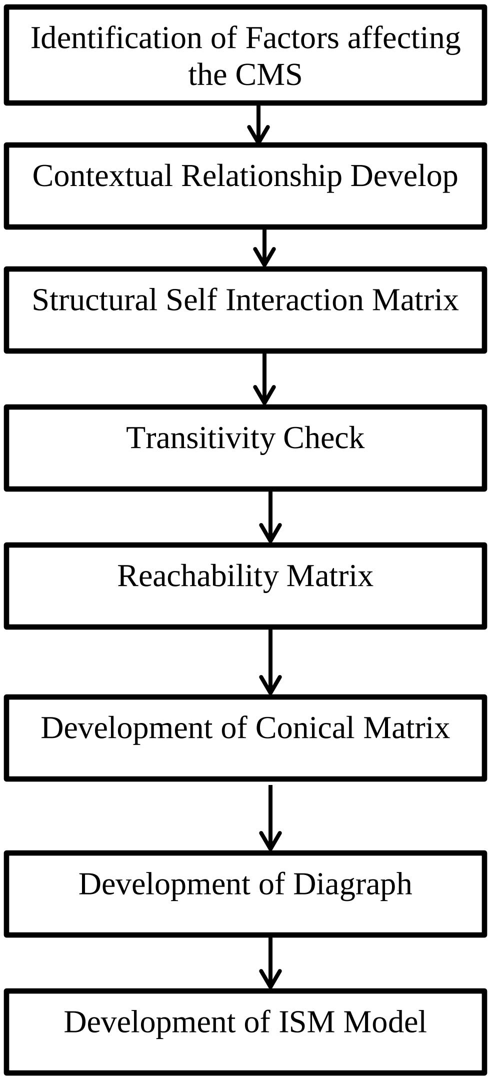

Fig 6.1 ISM methodology

Table 6.1 CMS Factors mean score

S. No.	CMS Factors	MeanScore	Rank
1.	Organizational structure	4.15	1
2.	Employee Training	4.08	2
3.	Support from Workers	3.98	3
4.	Management Support	3.90	4
5.	Long Term Planning	3.58	5
6.	Improved Supplier Relationship	3.42	6
7.	Flexible Manpower	3.34	7
8.	Support from Government	3.23	8
9.	Multi-Tasking	3.15	9
10	Organization Plans	2.97	10
11.	Availability of Funds	2.91	11
12.	Improved Lead Time	2.88	12
13.	Reduced Deffect	2.82	13
14.	Reduced Set up Time	2.79	14
15.	Floor Space Utilization	2.72	15
16.	Increased Safety	2.68	16
17.	Improved Quality	2.58	17
18.	Relative Profit	2.52	18

6.2 Demonstrating of CMS factors with MICMAC analysis

The phases, used to derive the technique, are illustrated below

Step 1: Identification of factors

The factors affecting the CMS system have been identified through literature survey and expert suggestions and shown in Table 6.2.

Table 6.2 CMS Factors

Sr. No.	**CMS Factors**
1	Organizational structure
2	Employee Training
3	Support from Workers
4	Management Support
5	Long Term Planning
6	Improved Supplier Relationship
7	Flexible manpower
8	Support from Government
9	Multi-Tasking
10	Organization Plans
11	Availability of Funds
12	Improved Lead Time
13	Reduced Defect
14	Reduced Set up Time

15	Floor Space Utilization
16	Increased Safety
17	Improved Quality
18	Relative Profit

Step 2: Inaugurating the contextual relationship between factors

To develop SSIM, the succeeding four symbolizations are used to indicate the inter-relationship between factor (*i* and *j*)

- *V* describes that factor *i* will distress the factor *j*
- *A* describes that factor *j* will distress the factor *i*
- *X* describes that factor *i* and *j* will distress each other
- *O* describes that factor *i* and *j* are isolated.

Based on the suitable inter-relationship between factors, the construction of SSIM is done. For constructing this SSIM table, these factors association was particularized in between the experts of industry and academia as shown in table 6.3.

Table 6.3 Structural self- interactive matrix

Factors	*18*	*17*	*16*	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	*V*	*A*	*V*	*V*	*V*	*X*	*X*	*V*	*V*	*V*	*X*	*V*	*V*	*V*	*V*	*V*	*V*
2	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*A*	
3	*V*	*A*	*X*	*A*	*A*	*O*	*O*	*V*	*A*	*V*	*A*	*V*	*A*	*A*	*X*		
4	*V*	*A*	*V*	*A*	*A*	*A*	*A*	*V*	*A*	*V*	*A*	*V*	*A*	*A*			
5	*V*	*A*	*V*	*O*	*V*	*A*	*A*	*V*	*V*	*V*	*A*	*V*	*V*				
6	*V*	*A*	*V*	*O*	*O*	*A*	*O*	*V*	*V*	*V*	*A*	*V*					
7	*A*	*A*	*A*	*A*	*A*	*A*	*A*	*V*	*A*	*A*	*A*						
8	*V*	*A*	*V*	*V*	*V*	*X*	*X*	*V*	*V*	*V*							
9	*V*	*A*	*A*	*A*	*A*	*O*	*O*	*V*	*A*								
10	*V*	*A*	*V*	*A*	*A*	*A*	*A*	*V*									
11	*A*	*A*	*A*	*A*	*A*	*A*	*A*										
12	*O*	*A*	*V*	*V*	*V*	*X*											
13	*V*	*A*	*V*	*V*	*V*												
14	*V*	*A*	*V*	*O*													
15	*V*	*A*	*V*														
16	*V*	*A*															
17	*V*																

For analyzing the factor in SSIM development, the subsequent four traditions have been utilized to represent the inter-relationship amongst factor (i and j)

- Symbol *V* is apportioned to cell (1, 16) as factors 1 properties to factors 16
- Symbol *A* is apportioned to cell (2, 9) as factors 2 properties the factors 9
- Symbol *X* is apportioned to cell (3, 4) as factors 3 and 4 properties each other
- Symbol *O* is apportioned to cell (6, 15) as factors 6 and 15 are unrelated.

Step 3: Extension of the RM

The reachability matrix is acquired from SSIM. The reachability matrix specifies the inter-relationship amongst barriers in the binary system. The different connections between barriers represented by symbols *V*, *A*, *X*, *O* used previously in SSIM are replaced by binary numbers of 0 and 1. The succeeding steps are used to substitute *V*, *A*, *X*, and *O* of SSIM to get RM.

- the (*i*, *j*) article in the SSIM is *V*, then the (*i*, *j*) admittance in the RM grows 1 and the (*j*, *i*) admittance matures 0
- the (*i*, *j*) article in the SSIM is *A*, then the (*i*, *j*) admittance in the RM matures 0 and the (*j*, *i*) admittance matures 1.
- the (*i*, *j*) article in the SSIM is *X*, then the (*i*, *j*) admittance in the RM matures 1 and the (*j*, *i*) admittance matures 1.
- the (*i*, *j*) article in the SSIM is *O*, then the (*i*, *j*) admittance in the RM matures 0 and the (*j*, *i*) admittance correspondingly matures 0.

The RM now momentous is approved as initial RM which is shown in Table 6.4.

Table 6.4 IRM

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	1
4	0	1	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	1
5	0	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	0	1
6	0	1	1	1	0	1	1	0	1	1	1	0	0	0	0	1	0	1
7	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
9	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1
10	0	1	1	1	0	0	1	0	1	1	1	0	0	0	0	1	0	1
11	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
12	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	0
13	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1
14	0	1	1	1	0	0	1	0	1	1	1	0	0	1	0	1	0	1
15	0	1	1	1	0	0	1	0	1	1	1	0	0	0	1	1	0	1
16	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1

- For (1,16) contact in the SSIM is *V*, henceforth the *(i, j)* contact in the RM progresses one and the (j, i) access develops zero
- For (2,9) contact in the SSIM is *A*, henceforth the *(i, j)* contact in the RM progresses zero and the (j, i) contact develops one
- For (3,4) access in the SSIM is *X*, henceforth the *(i, j)*contact in the RM progresses one and the (j, i) contact develops one

- For (6,15) contact in the SSIM is *O*, henceforth the *(i, j)*contact in the RM progresses zero and the (j, i) contact develops zero.

Then next step is to get the final RM that is acquired by integrating the transitivity. Transitivity is a related with 3 elements in a relation that if first element is linked with second element and second elements exhibits relation with third element then after relationship will be their between the first and second. Finally RM is as shown in Table 6.5 where1* is transitivity.

Table 6.5 Final RM

Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	1
4	0	1	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	1
5	0	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	0	1
6	0	1	1	1	0	1	1	0	1	1	1	0	0	0	0	1	0	1
7	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
9	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1
10	0	1	1	1	0	0	1	0	1	1	1	0	0	0	0	1	0	1
11	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
12	1	1	1*	1	1	1*	1	1	1*	1	1	1	1	1	1	1	1*	0
13	1	1	1*	1	1	1	1	1	1*	1	1	1	1	1	1	1	0	1
14	0	1	1	1	0	0	1	0	1	1	1	0	0	1	0	1	0	1
15	0	1	1	1	0	0	1	0	1	1	1	0	0	0	1	1	0	1
16	0	1	1	1*	0	0	1	0	1	0	1	0	0	0	0	1	0	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1

[*] The values which are changed because of transitivity

Step 4: Partitioning the RM

The reachability and predecessor set is developed for every factor can be seen in final RM. The RM involves the constituent its element and the other components in this it may aid to accomplish, however the forerunner set involves of the constituent itself and the other components that can support in accomplishing it. The crossing of arrays is derived for all the factors. The factors may fall in highest flat in the ISM ladder. The top most factors in the grading may not benefit to succeed any other component beyond its position in the grading. The higher factors are firstly recognized and then divided out from the other factors. Then, this procedure is executed a number of times till up to find out the factors in the next level. This process is sustained until or unless the level of each factor to be identified.

Table 6.6 Iteration 1

Factors	RS	AS	IS	Level
1	1,2,3,4,5,6,7,8,9,10,11,12, 13, 14,15,16,18	1,8,12,13,17	1,8,12, 13	
2	2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15 ,16,17	2	I
3	2,3,4,7,9,11,16,18	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
4	2,3,4,7,9,11,16,18	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
5	2,3,4,5,6,7,9,10,11,14,16,18	1,5,8,12,13,17	5	
6	2,3,4,6,7,9,10,11,16,18	1,5,6,8,12,13,17	6	

7	2,7,11	1,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18	7	
8	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	
9	2,7,9,11,18	1,3,4,5,6,8,9,10,12,13,14,15,16,17	9	
10	2,3,4,7,9,10,11,16,18	1,5,6,8,10,12,13,14,15,17	10	
11	2,11	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	11	
12	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	
13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	
14	2,3,4,7,9,10,11,14,16,18	1,5,8,12,13,14,17	14	
15	2,3,4,7,9,10,11,15,16,18	1,8,12,13,15,17	15	
16	2,3,4,7,9,11,16,18	1,3,4,5,6,8,10,12,13,14,16,17	3,4,16	
17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18	17	17	
18	2,7,11,18	1,3,4,5,6,8,9,10,12,13,14,15,16,17,18	18	

These levels would assist to develop the diagraph. In this chapter, the 18 factors along with their reachability set, antecedent set, intersection set and levels are depicted in Tables 6.6–6.15.

Table 6.7 Iteration 2

Factors	RM	AS	IS	Level
1	1,3,4,5,6,7,8,9,10,11,12, 13, 14,15,16,18	1,8,12,13,17	1,8,12, 13	
2	3,4,7,9,11,16,18	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
3	3,4,7,9,11,16,18	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
4	3,4,5,6,7,9,10,11,14,16,18	1,5,8,12,13,17	5	
5	3,4,6,7,9,10,11,16,18	1,5,6,8,12,13,17	6	
6	7,11	1,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18	7	
7	1,3,4,5,7,8,9,10,11,12,13, 14,15,16,18	1,8,12,13,17	1,8,12, 13	
8	7,9,11,18	1,3,4,5,6,8,9,10,12,13,14,15,16, 17	9	
9	3,4,7,9,10,11,16,18	1,5,6,8,10,12,13,14,15,17	10	

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

Table 6.8 Iteration 3

Factors	RS	AS	IS	Level
1	1,3,4,5,6,7,8,9,10,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	

2	3,4,7,9,16,18	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
3	3,4,7,9,16,18	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
4	3,4,5,6,7,9,10,14,16,18	1,5,8,12,13,17	5	
5	3,4,6,7,9,10,16,18	1,5,6,8,12,13,17	6	
6	7	1,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18	7	III
7	1,3,4,5,7,8,9,10,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	
8	7,9,18	1,3,4,5,6,8,9,10,12,13,14,15,16,17	9	
9	3,4,7,9,10,16,18	1,5,6,8,10,12,13,14,15,17	10	
11	1,3,4,5,6,7,8,9,10,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	
12	1,3,4,5,6,7,8,9,10,12,13,14,15,16,18	1,8,12,13,17	1,8,12,13	
13	3,4,7,9,10,14,16,18	1,5,8,12,13,14,17	14	
14	3,4,7,9,10,15,16,18	1,8,12,13,15,17	15	

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

Table 6.9 Iteration 4

Factors	RS	AS	IS	Level
1	1,3,4,5,6,8,9,10,12, 13, 14,15,16,18	1,8,12,13,17	1,8,12,13	
2	3,4,9,16,18	1,3,4,5,6,8,10,12,13,14,15,16, 17	3,4,16	
3	3,4,9,16,18	1,3,4,5,6,8,10,12,13,14,15,16, 17	3,4,16	
4	3,4,5,6,9,10,14,16,18	1,5,8,12,13,17	5	
5	3,4,6,9,10,16,18	1,5,6,8,12,13,17	6	
7	1,3,4,5,8,9,10,12,13, 14,15,16,18	1,8,12,13,17	1,8,12,13	

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

Table 6.10 Iteration 5

Factors	RS	AS	IS	Level
1	1,3,4,5,6,8,9,10,12,13,	1,8,12,13,17	1,8,12,1	

	14,15,16		3	
2	3,4,9,16	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
3	3,4,9,16	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	
4	3,4,5,6,9,10,14,16	1,5,8,12,13,17	5	
5	3,4,6,9,10,16	1,5,6,8,12,13,17	6	
7	1,3,4,5,8,9,10,12,13,14,15,16	1,8,12,13,17	1,8,12,13	
8	9	1,3,4,5,6,8,9,10,12,13,14,15,16,17	9	V
9	3,4,9,10,16	1,5,6,8,10,12,13,14,15,17	10	
11	1,3,4,5,6,8,9,10,12,13,14,15,16	1,8,12,13,17	1,8,12,13	
12	1,3,4,5,6,8,9,10,12,13,14,15,16	1,8,12,13,17	1,8,12,13	
13	3,4,9,10,14,16	1,5,8,12,13,14,17	14	
14	3,4,9,10,15,16	1,8,12,13,15,17	15	

15	3,4,9,16	1,3,4,5,6,8,10,12,13,14,16,17	3,4,16	
16	1,3,4,5,6,8,9,10,12,13,14,15,16,17	17	17	

Table 6.11 Iteration 6

Factors	RS	AS	IS	Level
1	1,3,4,5,6,8,10,12,13,14,15,16	1,8,12,13,17	1,8,12,13	
2	3,4,16	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	VI
3	3,4,16	1,3,4,5,6,8,10,12,13,14,15,16,17	3,4,16	VI
4	3,4,5,6,10,14,16	1,5,8,12,13,17	5	
5	3,4,6,10,16	1,5,6,8,12,13,17	6	
7	1,3,4,5,8,10,12,13, 14,15,16	1,8,12,13,17	1,8,12,13	
9	3,4,10,16	1,5,6,8,10,12,13,14,15,17	10	
11	1,3,4,5,6,8,10,12,13,14,15,1	1,8,12,13,17	1,8,12,1	

	6		3	
12	1,3,4,5,6,8,10,12,13,14,15,16	1,8,12,13,17	1,8,12,13	
13	3,4,10,14,16	1,5,8,12,13,14,17	14	
14	3,4,10,15,16	1,8,12,13,15,17	15	
15	3,4,16	1,3,4,5,6,8,10,12,13,14,16,17	3,4,16	VI
16	1,3,4,5,6,8,10,12,13, 14,15,16,17	17	17	

Table 6.12 Iteration 7

Factors	RS	AS	IS	Level
1	1,5,6,8,10,12,13, 14,15	1,8,12,13,17	1,8,12,13	
4	5,6,10,14	1,5,8,12,13,17	5	
5	6,10	1,5,6,8,12,13,17	6	
7	1, 5,8,10,12,13, 14,15	1,8,12,13,17	1,8,12,13	
9	10	1,5,6,8,10,12,13,14,15,17	10	VII
11	1, 5,6,8,10,12,13,14,15	1,8,12,13,17	1,8,12,13	

12	1, 5,6,8,10,12,13,14,15	1,8,12,13,17	1,8,12,13	
13	10,14	1,5,8,12,13,14,17	14	
14	10,15	1,8,12,13,15,17	15	
16	1,5,6,8,10,12,13,14,15, 17	17	17	

Table 6.13 Iteration 8

Factors	RS	AS	IS	Level
1	1,5,6,8,12,13, 14,15	1,8,12,13,17	1,8,12,13	
4	5,6,14	1,5,8,12,13,17	5	
5	6	1,5,6,8,12,13,17	6	VIII
7	1, 5,8,12,13, 14,15	1,8,12,13,17	1,8,12,13	
11	1, 5,6,8,12,13,14,15	1,8,12,13,17	1,8,12,13	
12	1, 5,6,8,12,13,14,15	1,8,12,13,17	1,8,12,13	
13	14	1,5,8,12,13,14,17	14	VII
14	15	1,8,12,13,15,17	15	VII
16	1,5,6,8,12,13,14,15, 17	17	17	

Table 6.14 Iteration 9

Factors	RS	AS	IS	Level
1	1,5,8,12,13	1,8,12,13,17	1,8,12,13	
4	5	1,5,8,12,13,17	5	IX
7	1, 5,8,12,13	1,8,12,13,17	1,8,12,13	
11	1, 5,8,12,13	1,8,12,13,17	1,8,12,13	
12	1, 5,8,12,13	1,8,12,13,17	1,8,12,13	
16	1,5,8,12,13,17	17	17	

Table 6.15 Iteration 10

Factors	RS	AS	IS	Level
1	1,8,12,13	1,8,12,13,17	1,8,12,13	X
7	1,8,12,13	1,8,12,13,17	1,8,12,13	X
11	1,8,12,13	1,8,12,13,17	1,8,12,13	X
12	1,8,12,13	1,8,12,13,17	1,8,12,13	X
16	1,8,12,13,17	17	17	XI

Step 5: Development of CM

The conical matrix is then constructed by banging collected factors in the identical levels, through rows and columns of the final reachability matrix. The drive power of a factor is plagiaristic by adding the numeral of ones in the rows and its dependence power by adding the figure of ones in the columns. Subsequent, drive power and dependence power grades are designed by benevolent uppermost ranks to the factor that have the supreme quantity of ones in the rows and columns correspondingly as shown in Table 6.16.

Table 6.16 Conical matrix

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Drive Power**
1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**17**
2	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
3	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**8**
4	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**8**
5	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**12**
6	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**10**
7	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**
8	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**17**
9	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**5**
10	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**9**
11	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**
12	**1**	**1**	**1***	**1**	**1**	**1***	**1**	**1**	**1***	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1***	**0**	**17**
13	**1**	**1**	**1***	**1**	**1**	**1**	**1**	**1**	**1***	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**17**
14	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**10**
15	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**10**
16	**0**	**1**	**1**	**1***	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**8**
17	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**18**
18	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**4**
Dependence	**5**	**18**	**13**	**13**	**6**	**7**	**16**	**5**	**14**	**10**	**17**	**5**	**5**	**7**	**6**	**13**	**1**	**15**	**176/176**

Step 6: Development of digraph

Constructed on the conical form of reachability matrix, the original digraph including transitive links is acquired. After removing the indirect links, a final digraph is developed. In this development, the top level factors is positioned at the top of the digraph and second level factors is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph as shown in figure 6.2.

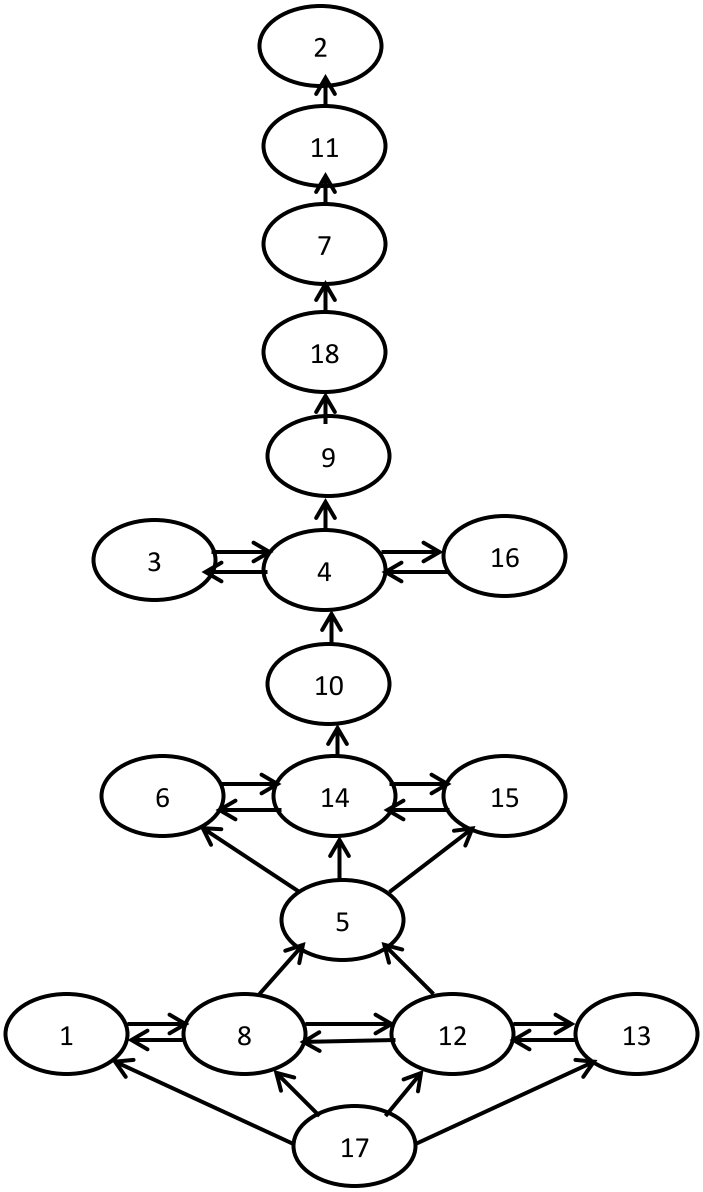

Figure 6.2 Digraph showing the levels of CMS factors

Step 7: Development of ISM model

Next step is to convert the above described diagraph into an ISM model by replacing nodes of the elements with factors as shown in Fig. 6.3.

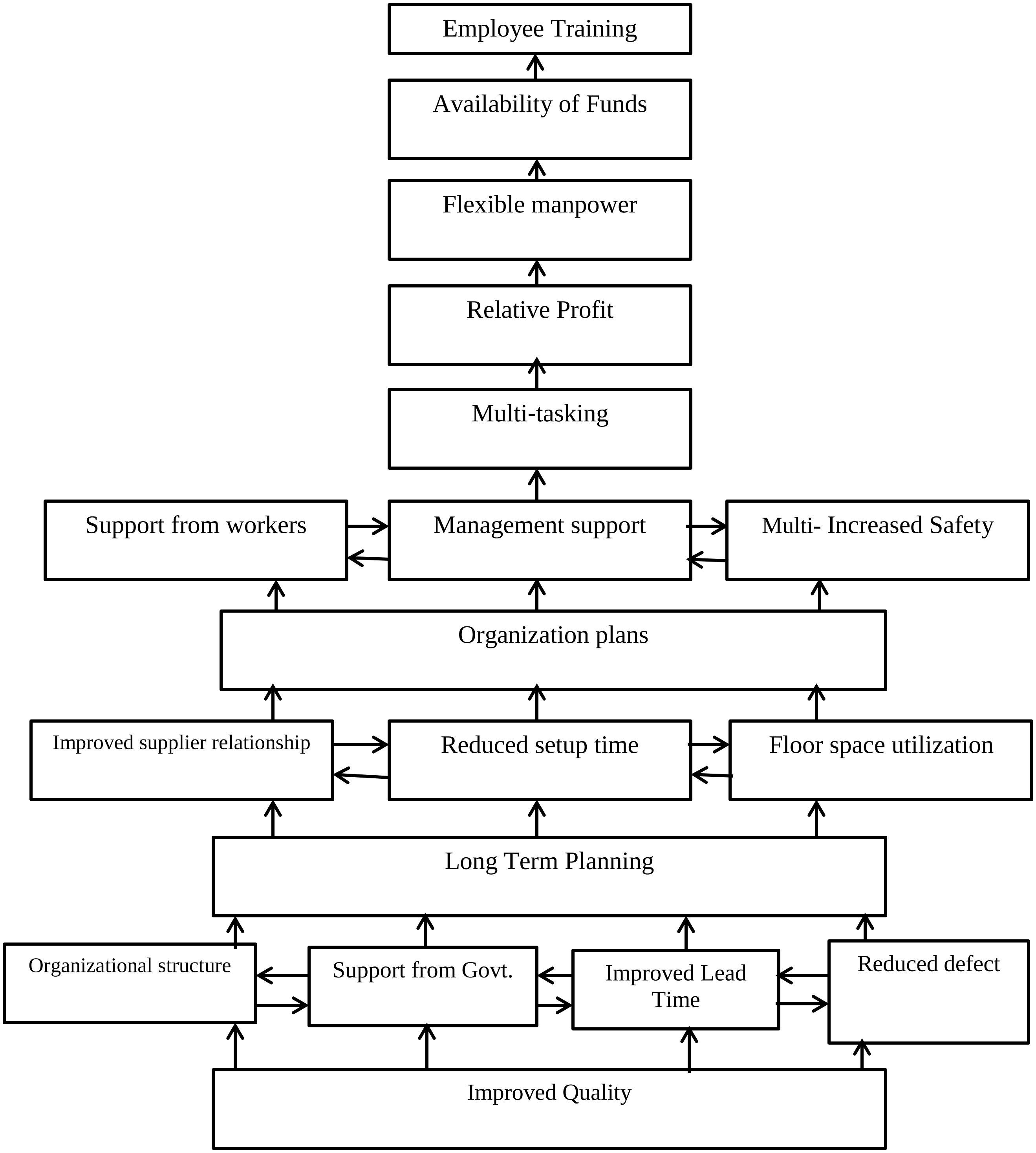

Figure 6.3 Interpretive structural model showing the levels of CMS factors

ISM model of CMS factors has been illustrated in Fig. 6.3 reveal that the management support in manufacturing industry is the most prominent factor for application of CMS.

The planning in the organization should be done in deep way instead of straight ways of those executives and subordinates allow sharing knowledge and ideas for better co-ordination among the team. Workers should be multitasking so that task can be complete on time and in efficient manner. ISM model also shows that the factors having higher driving power like availability of funds, long term planning, improved supplier relationship and improved lead time plays an import ant role in implementation of CMS. They need also more devotion because of their high driving and low dependency. Employee training and support from workers also plays a dynamic role in application of CMS. Reduced set up time, Flexible work force and multi-tasking comes after above discussed factors in hierarchy structure which states that these factors have moderate driving and dependency powers. Organizational structure has high dependency and less driving powers. This factor needs comparatively less attention as it will not yield greater impact on the overall system. Relative profit, increased safety and improved quality factors have highest dependency on other factors and lowest driving power. These factors are greatly affected by factors at all other levels.

Step 8: Matriced' Impacts Croises-Multiplication Applique an Classment Method

The MICMAC approach issued to investigate the driving and dependence power in respect of various factors. The driving and dependence power can be organized into four segments of quadrants as shown in Fig. 6.4

- Quadrant1: Independent quadrant;
- Quadrant2: Dependent quadrant;
- Quadrant3: Linkage quadrant;
- Quadrant4: Driving quadrant.

- Quadrant 1: Independent quadrant —this quadrant has factors those have weak drive power and weak dependence. In this quadrant we have no factor.
- Cluster 2: Dependence factors— this quadrant has factors those have weak drive power but strong dependence. In this quadrant we have nine factor i.e. Flexible man power, availability of funds, employee training, increased safety, multi-tasking, relative profit, organization plans, support from workers and management support (Factors7,11,2,16,9,18,10,3 and 4) respectively.

- Cluster 3: Linkage factors- this quadrant has factors those have weak strong drive power as well as strong dependence. In this quadrant we have no factor.
- Cluster 4: Driving factors-These factors have a strong drive power but weak dependence. In this cluster we have nine factors i.e. organizational structure, support from government, improved lead time, reduced defect, improved quality, long term planning, floor space utilization, improved supplier relationship and reduced set up time (Factors1,8,12,13,17,5,15,6 and14) respectively.

Driving Power

18	17																	
17					1,8,12,13													
16																		
15					IV								III					
14																		
13																		
12						5												
11																		
10						15	6,14											
9										10								
8													3,4,16					
7																		
6																		
5					I								II	9				
4															18			
3																7		
2																	11	
1																		2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Dependence

Figure 6.4 MICMAC analysis for CMS factors

6.3 CONCLUSION

The chapter presents the application of MICMAC analysis using ISM technique in an elaborative manner as shown in figure 6.3 and 6.4.The ISM technique is applied in affecting the design and application of Cellular Manufacturing System in an organization production system. These factors not only affect the edition of CMS in a particular industry but they also motivate the other organizations for its acceptance. Hence it becomes very much necessary to evaluate the impact of these factors for their better management. The scientific model presented in this chapter can be used to provide the dependency among various factors and establishes the hierarchy among them, which can aid the organizations to have better understanding and knowledge of the cellular manufacturing system.

It is found from the analysis; and the contributions can be concluded as

- The management support, long term planning, improved supplier relationship, improved lead time and availability of funds factors having high dynamic power and have high impact can be monitored effectively.
- Production organizations can have better understandings of the cellular manufacturing system
- Managers can have attention across changeover from traditional manufacturing system to CMS.
- Interpretive structural model with MICMAC analysis is investigated for the factors affecting CMS.

The main focus of this chapter is to facilitate the implementation of cellular manufacturing system in a manufacturing organization set-up.

CHAPTER 7

IDENTIFYING THE CELLULAR MANUFACTURING SYSTEM ENABLERS BY TISM APPROACH

7.1 INTRODUCTION

Cellular manufacturing system ensures the flexibility in the system along with the competitive production required in the organization. In cellular manufacturing the resources are utilized in such a manner that maximum utilization is taken from each and every resource like men, machine, method and material. Cellular manufacturing system is a kind of manufacturing system in which the machines are selected to form cells by identifying their similar processing and parts are grouped in family by their similarity in operation. There are various enablers in the system which supports the proposal and application of cellular manufacturing system. It is very important to deal with the various enablers that are collected with works review and brain storming with the officials. Since, in this chapter 11 enablers have been recognized from fiction survey. This chapter examines these enablers with total interpretive structural modelling (TISM) method and formulated an exemplary to elaborate the clarification of fundamental relations between them.

The target goal aim of this chapter is as follows:

- To recognize and order the enablers of cellular manufacturing system.
- To develop mutual interaction and interdependence of available enablers.
- To estimate the driving and dependent power of enablers of CMS.

7.2 An Overview of TISM

This is a method which is used for developing the correlation among the various enablers of CMS. The TISM approach is generated from ISM approach because ISM approach is lacking in providing the understanding of fundamental relations as well as not clear in available circumstances (Jain & Raj 2015). Thus, TISM methodology is usually followed over the practical implications of the ISM. The procedure of TISM approach is elaborated by Sushil (2012). TISM progression pledges along with the documentation of enablers those facilitate the industrial scenario that may be connected with apiece from various elements within a organization. The next step after documentation is different from the ISM due to the reason that in TISM we are recognizing the related circumstantial and understanding association (Jayalakshmi & Pramod 2015). Then the relationship among the various enablers is now rehabilitated into a Structure Self-Interaction Matrix (SSIM). Then next to the model, Reachability Matrix (RM) was formulated by SSIM. The transitivity is cheeked after the step. Transitivity of the circumstantial model is a elementary postulation made in the given technique. Then after this step, partitioning with iteration is developed in concluding reachability matrix. The digraph is developed according to the associations found in the partitioning and also communication matrix is drawn from the developed diagraph. The subsequent communication matrix and digraph is rehabilitated into model of TISM by substituting elements knots with elements (Sushil 2012). In end, the model is tested for hypothetical inconsistency and amendments are inserted in the model. Sympathetic of various stages as deliberated as shown in figure 7.1.

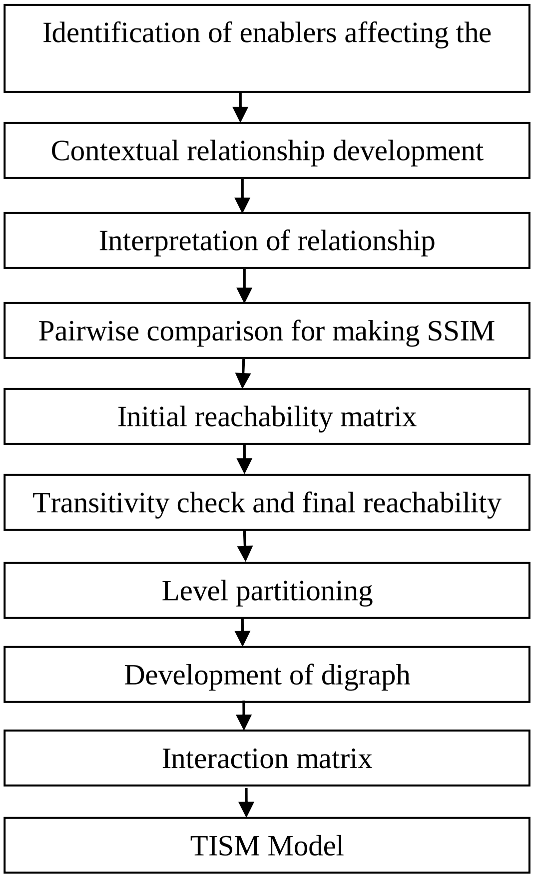

Figure 7.1: Flow diagram

7.3 ANALYSIS OF THE ENABLERS OF CELLULAR MANUFACTURING SYSTEMS:

The numerous ladders, which prime to the formulation of model, are demonstrated below:

Step 1: Documentation of enablers

The various enablers endorsing the CMS environment has been recognized through fiction survey, discussion and suggestions from the officials of industry and academia as shown in table 7.1.

Table 7.1: CMS Enablers

Sr. No.	Enabler (En)	Description
1	Reduced defect rate (En_1)	To get the effective production with minimum rejection rate to enhancing the profit.
2	Reduced Work in Process (En_2)	Smooth flow in production with minimum level of inventory during the work process.
3	Flexible workers(En_3)	Multi skilled man power is required to remain in competency level and to survive in the continuously changing market.
4	Management sustenance(En_4)	To get the funding and necessary support in various direction to achieve the excellence in the new era of competition.
5	Arrangement of organization (En_5)	Proper hierarchy with ease of communication from and within the departments to get the better production and control over the process.
6	Reduced Lead Time (En_6)	Improved rate of production result from lowering the lead time associated with machines.
7	Increased Automation (En_7)	To enhance the production newer automation methods are implemented to accelerate the productivity.
8	Improved productivity (En_8)	Increased productivity with quality standards and adequate rate of production.

9	Improved Quality(En_9)	Administration and control over the quality of product to continuously remain in competition.
10	Reduced Scrap/Waste (En_{10})	The level of waste is minimized to get the effective utilization of man and machine power.
11	Reduced Set up time (En_{11})	Better machine utilization with effective scheduling to get the maximum output from the machines as well.

Step 2: To develop contextual relationship between the enablers

To cultivate the CMS model, circumstantial relationship is required to estimate the type of the enabler and relationship between them. The circumstantial association will be ‘A should impact or will aid to enable B’ or ‘B will encourage or aid to enable A’. To acquire circumstantial association between the enablers is elaborated in crowd of officials from manufacturing and academic world.

Step 3: Explanation of relationship

This is important stage of TISM in that we obtained the connection across various enablers and their working. In TISM explanation, in which way the enablers boost or improve with each other and in which way they boost or improve each other is measured. This type of explanation was not in the ISM

Step 4: Couple contrast for SSIM

In this phase couple association of enablers with reacting the explanatory question as revealed in the preceding phase that will aid in drafting self-structural interaction matrix (SSIM). For each couple association, starting enabler must have equated from all other outstanding enablers. For each enabler assessment, the item should be ‘Y’ for relation and also motive is to be deliver and ‘N’ for no relation. Subsequently equating all enablers with each other, a corresponding association in the form of informative judgment–information base as per preceding stage, is acquired and is exposed in table 7.2.

Table 7.2: Structural self- interactive matrix (SSIM) for enablers of CMS

Enablers	1	2	3	4	5	6	7	8	9	10	11
En$_1$		**	*	**	**	*	**	**	**	*	**
En$_2$	**		**	**	**	**	**	*	*	**	**
En$_3$	*	*		**	**	**	*	**	**	**	*
En$_4$	*	*	*		*	*	*	**	*	**	**
En$_5$	**	**	**	**		*	*	**	**	**	**
En$_6$	*	*	**	*	**		**	**	**	*	**
En$_7$	**	**	**	**	**	**		**	**	**	*
En$_8$	**	**	**	**	**	**	**		**	**	**
En$_9$	**	**	**	**	**	**	**	**		**	**
En$_{10}$	**	**	**	**	**	**	**	**	**		**
En$_{11}$	**	**	**	**	**	**	*	**	**	**	

**- No relation (N)

*- Relation (Y)

Step 5: Initial reachability matrix

Depending on the skill chamber signified with ‘Y’ is substituted with ‘1’ and chamber characterized with ‘N’ is substituted with ‘0’. The reachability matrix thus derivative is known as initial reachability matrix which is represented in table 7.3.

Table 7.3: Initial reachability for enabler's matrix for CMS:

Enablers	1	2	3	4	5	6	7	8	9	10	11
En_1		0	1	0	0	1	0	0	0	1	0
En_2	0		0	0	0	0	0	1	1	0	0
En_3	1	1		0	0	0	1	0	0	0	1
En_4	1	1	1		1	1	1	0	1	0	0
En_5	0	0	0	0		1	1	0	0	0	0
En_6	1	1	0	1	0		0	0	0	1	0
En_7	0	0	0	0	0	0		0	0	0	1
En_8	0	0	0	0	0	0	0		0	0	0
En_9	0	0	0	0	0	0	0	0		0	0
En_{10}	0	0	0	0	0	0	0	0	0		0
En_{11}	0	0	0	0	0	0	1	0	0	0	

Step 6: Final reachability matrix is tested for transitivity check

This reachability matrix is checked for transitivity. When there are three elements X, Y and Z, there is relationship between X and Y and the relation is also their between X and Z then according to transitivity the relation will be their between Y and Z also. Then, final reachability matrix is acquired by integrating the transitivity. Final reachability matrix is as shown in table 7.4 where *1** is for transitivity.

Table 7.4: Final RM

Enablers	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
En$_1$		0	1	1*	0	1	0	1*	1*	1	0
En$_2$	0		0	0	0	0	0	1	1	0	0
En$_3$	1	1		0	0	0	1	1*	1*	0	1
En$_4$	1	1	1		1	1	1	1*	1	1*	1*
En$_5$	1*	1*	0	1*		1	1	0	0	1*	1*
En$_6$	1	1	1*	1	1*		1*	1*	1*	1	0
En$_7$	0	0	0	0	0	0		0	0	0	1
En$_8$	0	0	0	0	0	0	0		0	0	0
En$_9$	0	0	0	0	0	0	0	0		0	0
En$_{10}$	0	0	0	0	0	0	0	0	0		0
En$_{11}$	0	0	0	0	0	0	1	0	0	0	

Step 7: Partitioning between the levels

The partitioning can be done between the various enablers who are identical with the interpretive structural modeling. RM set and forerunner sets of the enablers can be formulated using table 7.4. Then after the juncture of the reachability and forerunner sets have been done. The enablers, for whom the reachability set and juncture set are identical, will lie top in TISM hierarchy. The top level enablers sustaining the said situation must be distant from the table and do the exercise till all the levels are formulated as presented in table 7.5 to 7.8.

Table 7.5: Level Partitioning for CMS (Iteration I)

Enabler	Reachability set	Antecedent Set	Intersection Set	Level
En_1	1,3,4,6,8,9,10	1,3,4,5,6	1,4,6	
En_2	2,8,9	2,3,4,5,6	2	
En_3	1,2,3,7,8,9,11	1,3,4,6	3	
En_4	1,2,3,4,5,6,7,8,9,10,11	1,4,5,6	1,4,5,6	
En_5	1,2,4,5,6,7,10,11	4,5,6	4,5,6	
En_6	1,2,3,4,5,6,7,8,9,10	1,4,5,6	1,4,5,6	
En_7	7,11	3,4,5,6,7,11	7,11	I
En_8	8	1,2,3,4,6,8	8	I
En_9	9	1,2,3,4,6,9	9	I
En_{10}	10	1,4,5,6,10	10	I
En_{11}	7,11	3,4,5,7,11	7,11	I

Table 7.6: Level Partitioning for CMS (Iteration II)

Enabler	Reachability set	Antecedent Set	Intersection Set	Level
En_1	1,3,4,6	1,3,4,5,6	1,4,6	
En_2	2	2,3,4,5,6	2	II
En_3	1,2,3	1,3,4,6	1,3	
En_4	1,2,3,4,5,6	1,4,5,6	1,4,5,6	
En_5	1,2,4,5,6	4,5,6	4,5,6	
En_6	1,2,3,4,5,6	1,4,5,6	1,4,5,6	

Table 7.7: Level Partitioning for CMS (Iteration III)

Enabler	Reachability set	Antecedent Set	Intersection Set	Level
En_1	1,3,4,6	1,3,4,5,6	1,3,4,6	III
En_3	1,3	1,3,4,6	1,3	III
En_4	1,3,4,5,6	1,4,5,6	1,4,5,6	
En_5	1,4,5,6	4,5,6	4,5,6	
En_6	1,3,4,5,6	1,4,5,6	1,4,5,6	

Table 7.8: Level Partitioning for CMS (Iteration IV)

Enabler	Reachability set	Antecedent Set	Intersection Set	Level
En_4	5	5	5	IV
En_5	5	5	5	IV
En_6	5	5	5	IV

Step8: Development of diagraph

After the partitioning between the levels the diagraph can be formulated as per the links that are developed for enablers in the form of charts. In transitive relation stepwise scrutinize of the enablers depends on the skill of formulator. Only significant transitive links are fabricated on the basis of their interpretation as depicted in figure7.2.

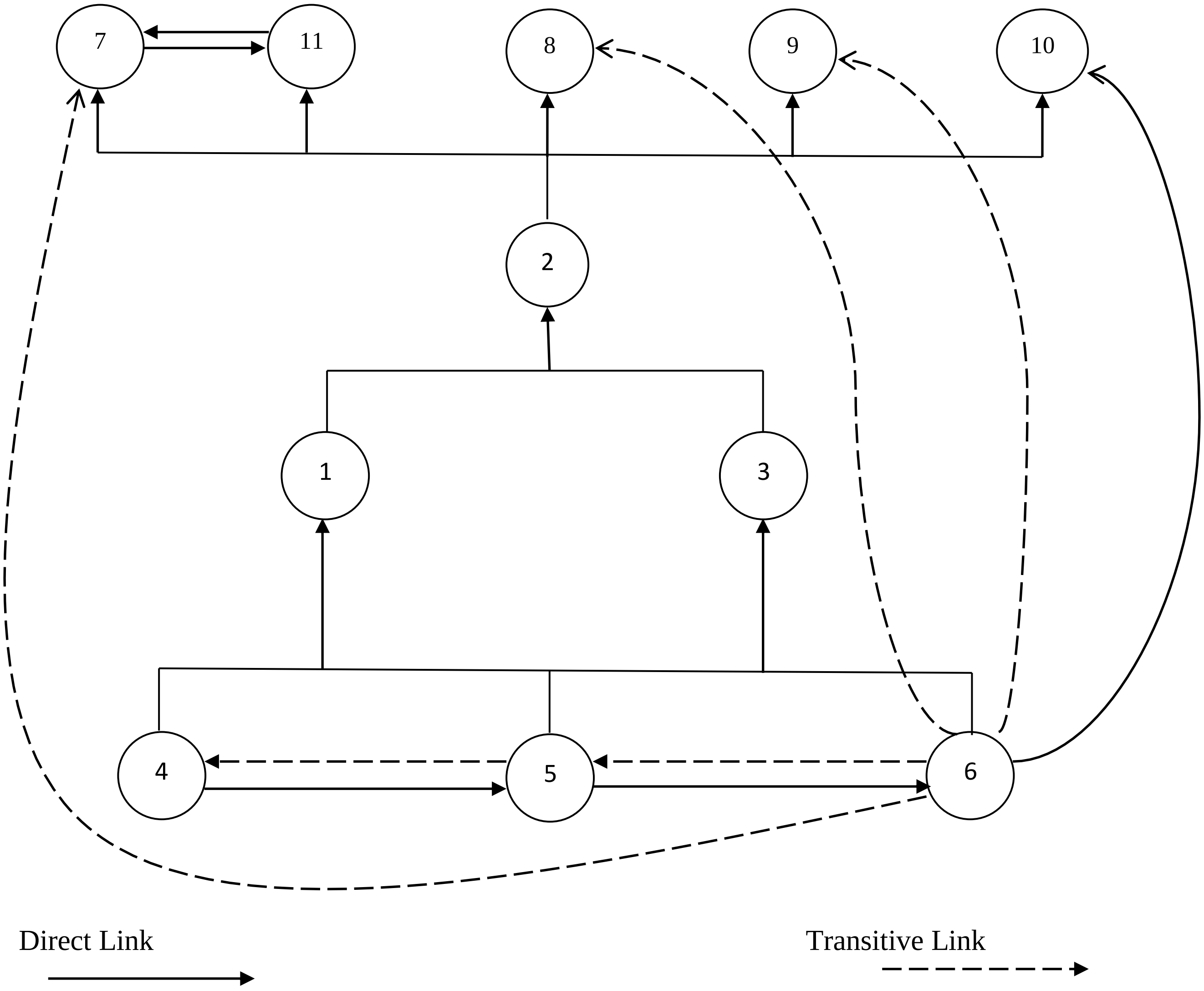

Figure 7.2: Digraph showing the levels of CMS

Step 9: Interaction matrix of CMS

After development of diagraph, the diagraph is replaced with the numeric entry for the various enablers. Table 7.6 shows the interaction matrix in which chamber entry 1 is construed with the skill of technique used. Now the chamber entry 1 in bold and italic form exhibit direct and significant transitive link respectively.

Table 7.9: Interaction Matrix of CMS

Enablers	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
En$_1$		0	**1**	*0*	0	0	0	*0*	*0*	0	0
En$_2$	0		0	0	0	0	0	**1**	**1**	0	0
En$_3$	**1**	**1**		0	0	0	0	*0*	*0*	0	0
En$_4$	**1**	0	**1**		**1**	0	0	*0*	0	*0*	*0*
En$_5$	***1***	*0*	0	*1*		**1**	0	0	0	*0*	*0*
En$_6$	**1**	0	***1***	0	*1*		*1*	*1*	*1*	**1**	0
En$_7$	0	0	0	0	0	0		0	0	0	**1**
En$_8$	0	0	0	0	0	0	0		0	0	0
En$_9$	0	0	0	0	0	0	0	0		0	0
En$_{10}$	0	0	0	0	0	0	0	0	0		0
En$_{11}$	0	0	0	0	0	0	**1**	0	0	0	

Step 10: TISM modeling

The modeling of TISM is developed with the use of Interaction matrix and diagraph of enablers affecting CMS. Entries are substituted with the explanation of enablers in the diagraph as depicted in figure 7.3.

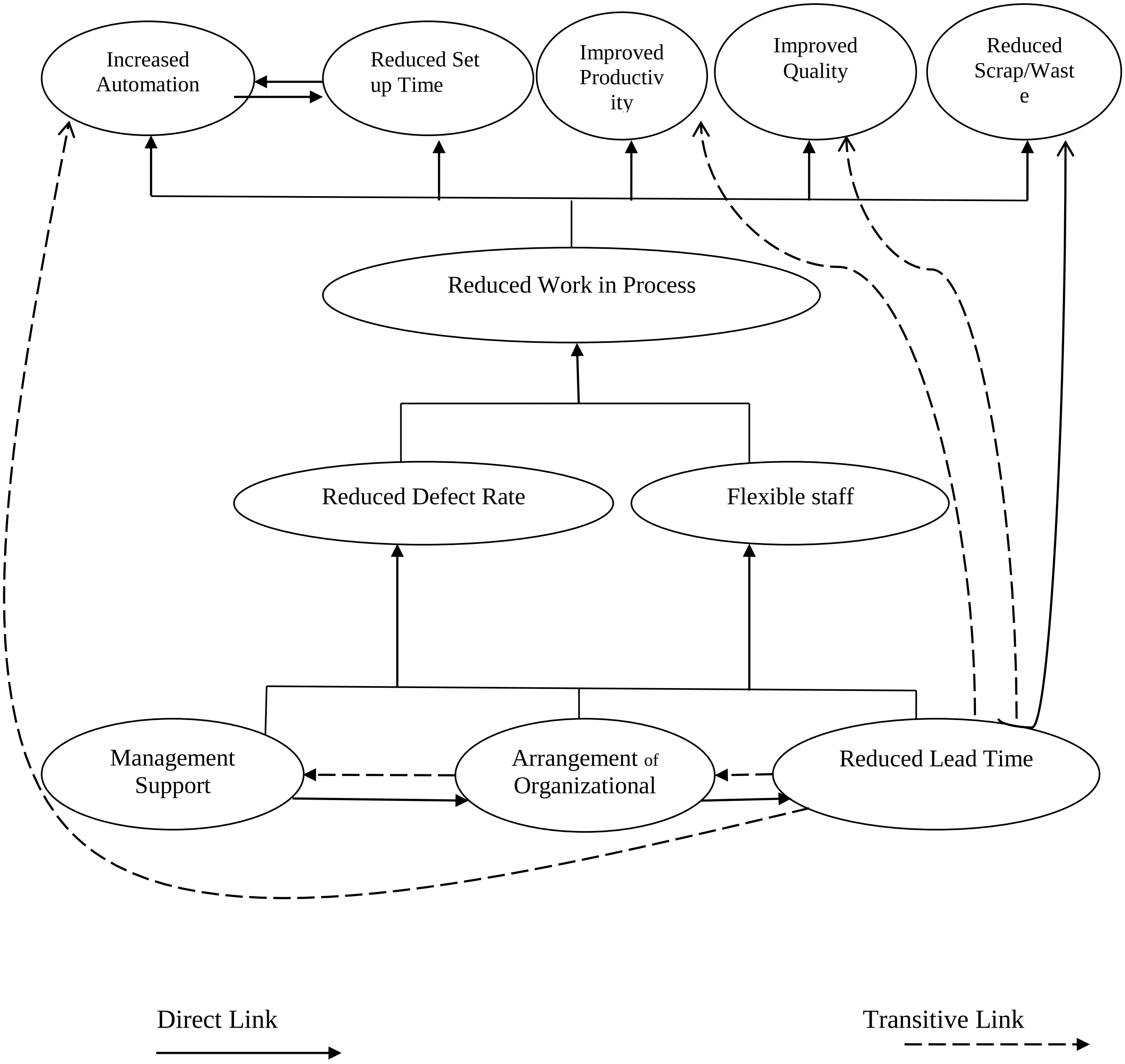

Figure 7.3: TISM Model of CMS

Step 11: MICMAC analysis

MICMAC stands for Matriced' Impacts Croises-Multipication Applique an Classment (cross-impact matrix multiplication applied to classification). The clusters have been formed as from the driver and dependence power of various enablers those quadrants are known as independent cluster, reliant on cluster, linkage cluster and driving cluster enablers. The cluster-wise features of these enablers are presented in figure 7.4. The aim of MICMAC analysis is to investigate the driving and dependence power of enablers.

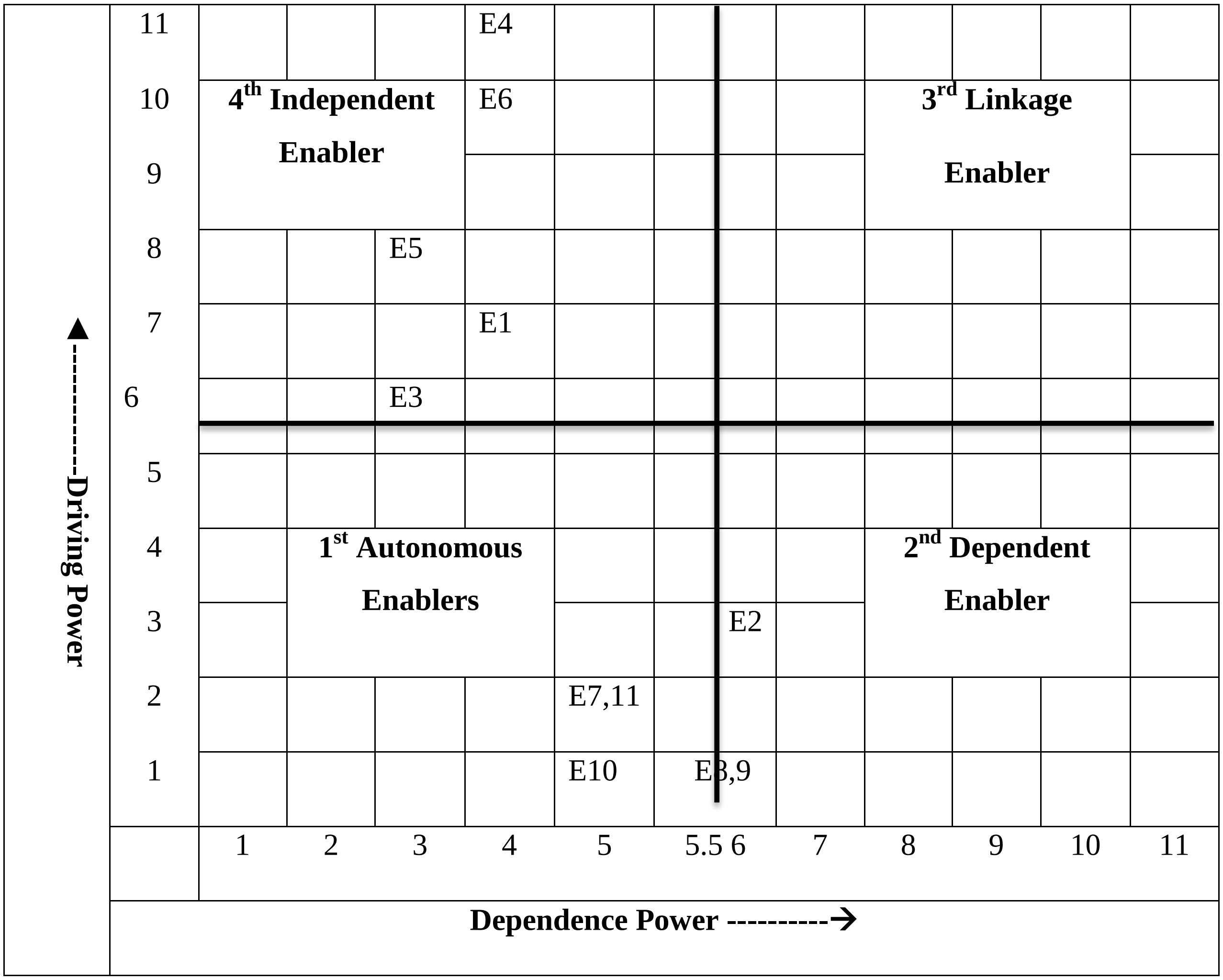

Figure 7.4: MICMAC analysis

Cluster 1: Self-directed enablers - These enabler shows a poor driving control and poor reliance. In this bunch we have 3 enabler's *i.e.* increased automation (enabler seven), Reduced scrap/waste (enabler ten), and reduced set up time (enabler eleven).

Cluster 2: Dependent enablers- These enablers have poor dynamic power but sturdy reliance. In this bunch we have 3 enablers *i.e.* reduced work in process (enabler two), improved productivity (enabler eight), and improved quality (enabler nine). All enablers in this group are on edge line revenues as they are less poor in reliance power it moves in self-directed cluster.

Cluster 3: Linkage enablers- The enablers which have a sturdy driving power as well as durable dependence. No enabler lies in this cluster in this study.

Cluster 4: Driving enablers- These enablers have a sturdy driving power but poor reliance. 5 enablers belong are coming in this cluster *i.e.* reduced defect rate (enabler one), flexible staff (enabler three), support from top level management (enabler four), organizational arrangement (enabler five), and reduced lead time (enabler six).

7.4 CONCLUSION

The different key enablers have been identified by total interpretive structural modelling technique. It categorizes the impact of enabler, common association, comparative significance and linkage of various enablers with the help of TISM and MICMAC approach. Incorporated exemplary of CMS has been settled by using TISM and MICMAC approach. This scientific prototypical is engaged to establish an appropriate policy for the crafting and application of CMS in any manufacturing industry. The results of this research license the organization to professionally service their assets to concentration deliberation on the most substantial enablers. Conclusion will deliver awareness into the enablers that inspiration the selection of cellular manufacturing system. Industries will also get the attractiveness, customer satisfaction and ecological alarm *etc.* from the above findings it will aid the management to deal and understandings of cellular manufacturing system.

CHAPTER 8

WEIGHT ESTIMATION OF CRITERIA AND RANKING BY ENTROPY, MOORA AND VIKOR METHODOLOGY

8.1 INTRODUCTION

Several studies are devoted to examining the potential benefits of CMS implementation. The common conclusion of these studies is that the advantages associated with the CMS implementation are numerous. Successful implementation of CMS will produce decreased labor costs, improved flexibility and product diversity, productivity enhancement, better responsiveness, and improved machinery utilization Because of the globalization and development of markets, advancement in technologies and the fast flexible requirements and demands of patrons have forces the system of competitiveness standards to change quickly (Singh et. al., 2010). The production sector universally has witnessed strong changes in the later part of 20th century. Industrialization has given force to the concerns of production administrations to produce their parts, with customer satisfying needs at minimum possible cost. “Reduction in cost without negotiating in quality” has become the target of each and every production association, to remain their survival in the dynamic environment (Sundharam et. al., 2013). In the production organization, component quality has become a key factor in predicting a firm’s success or a failure in a dynamic environment. In the present scenario for obtaining the maximum efficiency and competency in the market facilitators should be taken in the mind of managers. For selecting and ranking the facilitators this paper provides the MCDM approaches. In this paper weightage of facilitators has been found by entropy approach and then ranking has been found and compared through MOORA and VIKOR methods.

From chapter 6 and 7 recognized driving enablers and factors which considered as facilitators in application of cellular manufacturing system. The system requires ranking and studying these facilitators of CMS. There are five facilitators identified from the literature concluded from chapter 6 and 7 and two criteria's are considered *i.e* beneficiary and non-beneficiary criteria. Flexibility denoted as C1, Profit denoted as C2 are considered as beneficiary criteria because they are always dealt with the margin of profit whereas resources denoted from C3 and capital investment abbreviated as C4 are considered as non-beneficiary criteria as they do not subsidize benefit directly to an organization. The chapter investigates the different criteria by calculating their weightage by Entropy method and then ranks the facilitators and compares them with MOORA and VIKOR Technique. The facilitators of CMS recognized are shown in table 8.1.

Table 8.1 Facilitators of CMS

Sr. No.	**Facilitators**
1	Reduced defect rate(F1)
2	Flexible Work Force (F2)
3	Management Support (F3)
4	Arrangement of Organization(F4)
5	Reduced lead time (F5)

The main objectives this chapter is:

- To find the weights of the different alternatives affecting initiators of CMS.
- To find rankings of CMS initiators for implementing the CMS

8.2 ORGANIZATION

In the past available fiction, numerous multi-principles decision making (MCDM) methods are available like graph theoretic approach (GTA), data envelopment analysis (DEA), grey relational analysis (GRA), compromise ranking method (VIKOR), preference selection index (PSI), analytic hierarchy process (AHP), analytic network process (ANP), MOORA, preference ranking organization method for enrichment evaluation method (PROMETHEE), technique for order preferences by similarity to ideal solution (TOPSIS), weighted Euclidean distance-based approach (WEDBA), etc. Though numerous of MCDM techniques are available in the literature to assist the decision makers in making good judgements. It is concluded that in all these methods, the position of alternatives is affected by the weight of criteria. Moreover, some of these methods are quite difficult to understand and complex to implement requiring extensive mathematical knowledge.

8.2.1 Entropy Approach: Entropy principal is a kind of method in which weightage is calculated for the alternatives. It is the easiest technique ever suggested by Shannon in 1948. This method follows the simplest way for finding the weights of the elements with easy calculations. As from decrease the statistics entropy, weight of concerned alternative is increase due to the reason that in real situation we always choose that value whose doubt level is low (Huang et, al., 2015). This method has advantage compare to other MCDM method (Rhodes et, al., 1995) is

- The result is reliable with all the existing information.
- Time to solve is minimum
- Simple in nature
- Validity can be tested
- Easy calculation

The technique has found the most suitable method in various available MCDM approaches. From literature its applicability and adaptability can be measured and ensured.

8.2.2 MOORA Method: MOORA means Multi-Objective Optimization on the basis of Ratio Analysis. MOORA technique tackles instantaneously an optimization of available contradictory commitment concern to certain criteria. Technique was familiarized by Brauers in 2004. It is used finding the best alternatives and ranking among the various available inputs. This method is comparatively guileless method as from other MCDM approaches and it is very easy to deal with the above method. Now this method becomes the most popular method in the researchers.

Merits of MOORA technique (Karande et. al., 2012) is

- Simple in calculations
- Easy to understand
- Consume less time

This method has been found as the most suitable method where researchers have to find the ranking among the complex decisions.

8.2.3 VIKOR Analysis:

Vlsekriterijumska Optimizacija I Kompromisno Resenje is the best method to get the best ranking among the various available factors. Opricovic in 1998 elaborated the analysis for finding the optimal solution and ranking of multifarious organization with complex alternatives (Opricovic 1998). The technique is used to find the best alternative and to provide the ranking among the various possible complex alternatives.

Merits of VIKOR approach

- v factor is depend on the decision maker
- best solution for ranking of the alternatives
- Easy to understand

8.3 DISTRIBUTION OF WEIGHT WITH ENTROPY

In this phase, weightage is formulated with Entropy approach method is described below as

Step 1: Ranking to facilitators contrary to criteria

The starting step of this chapter is to identify the various facilitators of CMS. Then after identification of facilitators their weights are calculated as per the suggestion from the professionals from industries and academia. The experts are asked to fill the ranking on the Likert's scale between 1 to 5.

Table 8.2 Distribution of Weight with Entropy method

FC/CT	**Value Allocated to FC**				**Consistent FC**			
	CT 1	***CT 2***	***CT 3***	***CT 4***	***CT1***	***CT2***	***CT3***	***CT4***
Fc1	4	3	2	3	0.2105	0.1666	0.1111	0.1666
Fc2	5	5	4	4	0.2631	0.2777	0.2222	0.2222
Fc3	3	5	3	3	0.1578	0.2777	0.1666	0.1666
Fc4	2	3	5	4	0.1052	0.1666	0.2777	0.2222
Fc5	5	2	4	4	0.2631	0.1111	0.2222	0.2222
nj					0.9687	0.9649	0.9736	0.9941
1-nj					0.0312	0.0350	0.0263	0.0058
wj					0.3174	0.3556	0.2671	0.0597

Step 2: Normalization:

Normalization has been done for further analysis of the facilitators. Available ratios to normalize the data are Weitendorf ratio, Total ratio, Stopp ratio, Schärligratio, Körth ratio, *etc*. have been exercised by various scholars for normalizing the matrix (Maniya, 2011). Normalization has been done in this step. Normalization method is explained in equation 1 the equation for total ratio is

$$\mathrm{Xij} = \frac{\mathrm{Xij}}{\sum_{\mathrm{i=1}}^{\mathrm{m}} \mathrm{Xij}} \quad (\mathrm{j}=1, 2, 3\ldots..\mathrm{n}) \qquad (1)$$

Step 3: nj value Calculation

Nj value of criteria is derived after normalization of facilitators by consuming equation 2

Equation for nj value is

$$n_j = -k \sum_{i=1}^{n} X_{ij} * \ln(X_{ij}) \qquad j = 1,2\ldots\ldots m \qquad (2)$$

Where k = 1/ ln (n)

Step 4: Calculation of Weight of criteria

The weight for each criteria is calculated by using equation 3 by using Nj value for criteria. The weight Wj value is the weightage of each criteria with respect to its facilitators.

Equation for calculating weight for 'j' criteria is

$$w_j = \frac{1-N_j}{\sum_{j=1}^{n}(1-N_j)} where\, j = 1, \ldots, n. \qquad (3)$$

Table 8.2 representing weightage calculation of criteria, in which is derived after using equation (3), beneficiary criteria i.e. Flexibility (C1) and Profit (C2) criteria are getting highest weightage *i.e.*31.74 and 35.56 weightage respectively explains that both of these criteria got 67.30% of total weight. After that Non beneficiary criteria i.e. Resources (C3) and Capital investment (C4) are getting 26.71 and 5.97 weightage respectively i.e. 32.68% of total weight that is lower than the weightage of beneficiary criteria.

8.4 FACILITATORS RANKINGWITH MOORA AND VIKOR APPROACH

In this step the ranking of facilitators have been identified derived from its criteria weight using MOORA and VIKOR methods.

8.4.1Ranking of CMS facilitator by MOORA method

Multi objective optimization, also known as multi criteria or multi attribute optimization is the process of instantaneously optimizing two or more contradictory features (objectives) applied to definite restraints. The MOORA technique, first familiarized by Brauers (2004) is way that a multi objective optimization method that can be effectively used to solve numerous types of multifarious decision making problems in the engineering.

Phases followed to derive ranking of facilitators by MOORA method are as follows (Karande and Chakraborty 2012 & Attri and Grover 2014):

Step 1**:** Normalization

The very first step is to normalize the respective weight of the facilitators. This step is previously illustrated in section 8.3 when exercise of weight of criteria has been done with entropy method as shown in table 8.2

Step 2: Assessment of facilitators (yi)

In case of multiple Goals, normalized value added for all beneficial goals (case of maximization) and subtract for all non-beneficial goals (case of minimization). Then final equation is for y_i is

$$y_i = \sum_{j=1}^{g} Xij \; - \sum_{j=g+1}^{n} Xij \qquad (4)$$

In this equation g represents the number of valuable objectives, (n-g) is the number of non-valuable objectives and Yi is the regularized calculation value for ith enabler. This is seen many times that some objectives are more significant over others. To provide importance to an objective, it is burgeoned with its concerned weight. When these goal weights are taken into consideration then new equation for Yi is

$$yi = \sum_{j=1}^{g} wj * Xij - \sum_{j=g+1}^{n} wj * Xij \quad (j=1, 2, 3\ldots..n) \qquad (5)$$

Where wj is the weight of j^{th} goal.

Step 3: CMS facilitators Classification

The value for yi can be +ve or –ve contingent of the totals of its favorable objectives and non-favorable objectives in the Table 8.3. A general order of yi exhibits the final order. Hence, the optimal enabler and factors has the highest yi value, while the worst enabler has the lowest yi value. In this analysis facilitators Fc2 and Fc3 i.e. Flexible workforce and top management support got the first and second rank respectively and facilitator Fc4 (Organizational structure) got the last rank.

Table 8.3: Facilitator Ranking with MOORA Method

Facilitators Ranking with MOORA Method						
FC/CT	Flexibility (0.3174)	Profit (0.3556)	Resources (0.2671)	Capital Investment (0.0597)	yi Value	Rank
Fc1	0.21053	0.16667	0.111111	0.166667	0.086456	3
Fc2	0.26316	0.27778	0.222222	0.222222	0.109672	1
Fc3	0.15789	0.27778	0.166667	0.166667	0.094423	2
Fc4	0.10526	0.16667	0.277778	0.222222	0.005193	5
Fc5	0.26316	0.11111	0.222222	0.222222	0.050396	4

8.4.2 Facilitator Ranking using VIKOR method:

VIKOR approach used comprehensive explanation by consuming convenience weight. The weight can be judged as per the knowledge of expert. This is used to regulate a conciliation solution to identify the opinion of experts (Wei et. al., 2008). The approach is used by various investigators to choose a locality (Wang et. al., 2009).

Following are the steps carried out in VIKOR technology are as follows:

Step 1: Normalization:

Normalization can be derived by following equation 1 for the ranking calculation by MOORA method as shown in table 8.3.

Step 2: E_i assessment Calculation

The value of E_i is calculated, that shows the remoteness of each CMS facilitator from the optimistic perfect solution.

E_i value for valuable issue:

$$\text{Ei} = \sum_{j=1}^{n} \text{wj}[(\text{Xijmax} - \text{Xij}) / (\text{Xijmax} - \text{Xijmin})] \qquad (6)$$

E_i value for non-valuable issue:

$$\text{Ei} = \sum_{j=1}^{n} \text{wj}[(\text{Xij} - \text{Xijmin}) / (\text{Xijmax} - \text{Xijmin})] \qquad (7)$$

E_i value for CMS facilitator can be derived by equation 6 and 7 and shown in table 8.4.

Step 3: *F_i assessment*

F_i assessment, which is the distance of the ith alternative to the undesirable superlative resolution.

F_i significance for valuable issue:

F_i = Max of [wj(Xijmax - Xij) / (Xijmax - Xijmin)] (i=1, 2....., n) (8)

F_i significance for non-valuable issue:

F_i = Max of [wj(Xij - Xijmin) / (Xijmax - Xijmin)] (i=1, 2....., n) (9)

F_i significance for CMS facilitator can be derived by using equation 8 and 9 and as shown in table 8.4.

Step 4: P_i assessment

P_i assessment is negative arrogance of CMS facilitators that means minimum assessment of Pi comes as finest facilitator and higher value of it comes up as pathetic facilitator.

P_i= v [(E*i*– Eimin) / (Eimax – Eimin)] + (1 – v) [(Fi – Fi min) / (Fi max – Fi min)] (10)

Here we have considered the value of VIKOR constant v = 0.5. The v is larger than 0.5, the directory of Pi will incline to mainstream agreement; when v is less than 0.5, the index Pi will designate majority negative boldness; in general, v = 0.5, i.e. compromise attitude of evaluation experts. Pi assessment of issues is derived by using equation 10 as shown in table 8.4.

Table 8.4: Order of Facilitator with VIKOR methodology

FC/ CT	NORMALIZED FACILITATORS				Ei	Fi	Pi	Order
	CT1 (0.3174)	**CT2 (0.3556)**	**CT3 (0.2671)**	**CT4 (0.0597)**				
Fc1	0.2105	0.1666	0.1111	0.1666	0.3738	1	0.6035	3
Fc2	0.2631	0.2777	0.2222	0.2222	0.2483	0.5	0	1
Fc3	0.1578	0.2777	0.1666	0.1666	0.3369	1	0.573	2
Fc4	0.1052	0.1666	0.2777	0.2222	0.8540	1	0.8028	5
Fc5	0.2631	0.1111	0.2222	0.2222	0.5917	1	0.7834	4

Step 5: Order

The ranking of Pi is derived in the study. The best facilitators have the lowest Pi value, as Pi value increases, ranking of facilitators will also increase. Ranking of CMS facilitators is illustrated in table 8.4. Table 8.4 represent Pi value of Flexible workforce (F4) is zero and its minimum in all values of facilitators, hence it occurs at first rank. Ranking of other facilitators is done accordingly and represented in table 8.4.

8.5 OUTCOME

This segment equates the findings acquired from MOORA and VIKOR approach. Rankings are calculated from the two said techniques. y_i assessment from MOORA method is highlighted by orange line and P_i assessment from VIKOR investigation is represented by sky blue line in figure 8.1. Higher Y_i and lowest P_i values represent best facilitator and vice versa. Y_i and P_i value of all facilitators provide us a concise way to compare the results of MOORA method and VIKOR analysis.

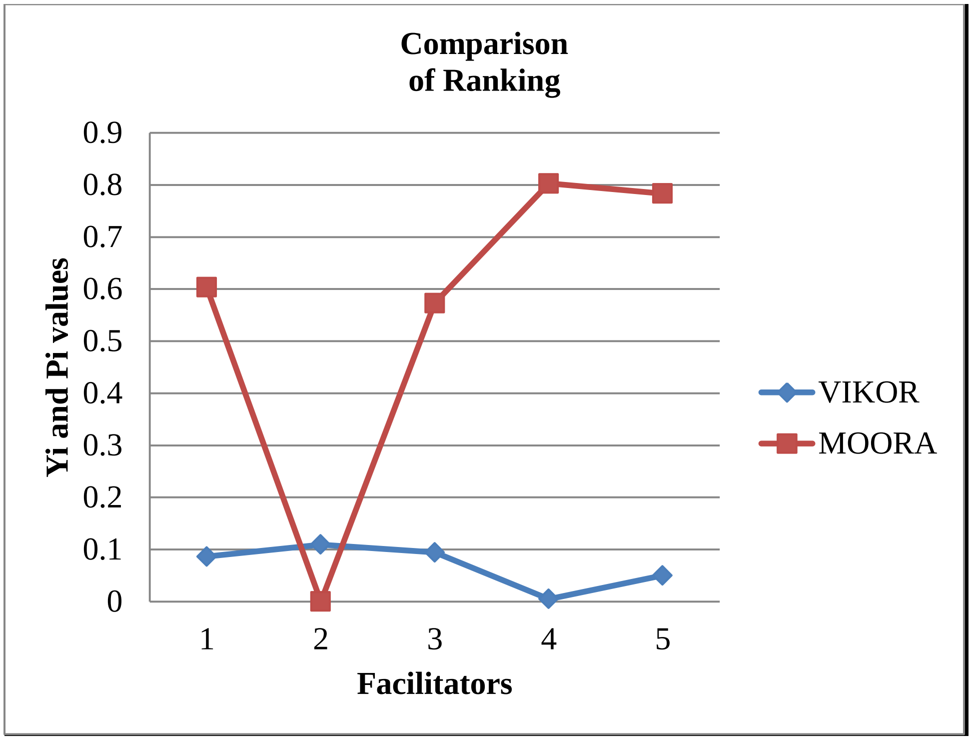

Fig. 8.1: Ranking Comparison of CMS Facilitators

This chart inspects the facilitators those have least gap among Y_i and P_i values as best facilitator and vice versa. Flexible Workforce (facilitator 2) achieved highest Y_i value as 0.1096 and lowest P_i value as 0. Therefore it occurs at first rank in comparison with all other facilitators. After Flexible Workforce, facilitator 3 (Top management support) gets Y_i value as 0.0944 and P_i value as 0.0573 which shows that facilitator 3gets second rank in all facilitators. Facilitator 4 (organizational structure) have maximum distance between Y_i and P_i value as shown in figure 8.1, which indicates that facilitator 4 is less effective among all facilitators. The final ranking of all facilitator has been done consequently with the help of graph in figure 8.1 and available in table 8.4.

Table 8.4 Final ranking of CMS facilitators with comparison of MOORA method and VIKOR analysis

Facilitator	**Y*i* Value**	**P_i**	**Rank**
Fc1	0.0864	0.6035	3
Fc2	0.1096	0	1
Fc3	0.0944	0.573	2
Fc4	0.0051	0.8028	5
Fc5	0.0503	0.7834	4

This ranking of CMS facilitators can be used as an aid to develop a suitable strategy for designing and implementation of CMS in any organization. This finding will allow the management to efficiently utilize their resources to focus attention on the most significant facilitator. These results will provide an insight into the facilitator that influences the choice of CMS. Organization will also achieve the competitiveness, customer satisfaction and environmental concern *etc.* from the above findings which will help in moving towards advanced manufacturing practices.

8.6 Conclusion

In this analysis, facilitators are selected through the light of reduced defect rate, flexible workforce, top management support, organizational structure and reduced lead time. Decision makers for the facilitators in cellular manufacturing system involve the complex evaluation process due to imprecise information. The complexity further increase as the number of alternatives and their selection criteria increases. In this regards MCDM approaches are recommended for facilitator's assessment in cellular manufacturing system for the selection of best alternative from a number of alternatives. In this regards same problem is illustrated and compared by two methods, i.e., MOORA and VIKOR where weightage of facilitators are found by entropy approach. In which the flexible workforce is found to be the best alternative by the two methods and organizational structure is found to be the worst alternative. Overall ranking of alternatives are compared shown in Figure 8.1. The some disparities among the ranking of alternatives may be due to the diverse opinion given by the decision makers. And the weights of criteria differ according to the methods due to the dependency or independency of facilitators. Besides a large number of calculations these methods are very simple and easily comprehensible which can handle a large number of selection criteria. The results obtain from this study can help in making strategic and tactical decisions for a firm to tackle the implementation of CMS. Application of this method in a wide range of selection problems in CMS is the direction for future research work and can be analyzed by TOPSIS and goal programming. TOPSIS and goal programming which can be used for decision making problem, is the process of finding the best option from all of the alternatives.

CHAPTER 9

CALCULATION OF SUITABILITY OF CMS BY AHP METHOD

9.1 INTRODUCTION

The production sector universally has observed strong changes in the past available literature (Ahuja and Khamba 2008). Globalization has given pressure to the officials of production organization had to produce their components, with adequate acceptance at a reduced cost. The reduction in cost deprived of negotiating in quality' has become the target of each and every production organization, to alive in the dynamic workplace. In the production industry, component quality has become a key factor in predicting a firm's success or a failure in worldwide organizations (Schiele and McCue 2010). Cellular manufacturing system is a type of manufacturing system which takes the advantage of medium flexibility along with the medium production. In continuously changing dynamic and competitive environment cellular manufacturing is found to be most suitable manufacturing method. Adoption of cellular manufacturing system is not an easy task it need a careful review of the system and some measurable parameters in the system so that one can understand the depth of the system. AHP is an approach from which we can take a decision among the various available alternatives. AHP makes the selection process very transparent (Abdul et. al., 1999). It also confesses on the concerned merits of alternative solutions for a multi criteria decision making problem (Biswas et. al., 2017). In the present work, three alternative configurations of the manufacturing system including CMS have been analyzed and an attempt has been made to select the best one. But decision making is a typical activity for the managers because the implementation of cellular manufacturing system will involve reshuffling of machines and installation of new machine tools. This will take time and production may be stopped for some time. Hence, it is important that proper consideration should be given to all the aspects of implementation before a final decision is taken.

The objective of this chapter is

- to identify the levels of hierarchy of AHP then attributes and sub attributes of the system
- to find out the suitability index for the best manufacturing system

9.2 METHODOLOGY

Analytic hierarchy process is utilized to find the suitability of cellular manufacturing system in Indian industries. This approach can be used for simultaneous optimization of machining process also with different processing parameters (Selvaraj et. al., 2017). The brief of AHP approach is expressed here as:

9.2.1 Overview

Saaty (1980) illustrated a multi criteria decision method Analytic Hierarchy Process which is the best method to identify and for rankings of various complexes inter related attributes. Where "logical" elements show that the objective or difficulty is divided into its native attributes and sub attributes. The hierarchy of the system comprises the fundamental points to be combined in context of the foremost target. The AHP now a day is commonly used in various decision techniques such as in education sector, manufacturing sector, and automobile sector etc. AHP is the best suitable method for conflicting decisions. The method is suggested a model for multi-attribute utilization attitude to calculate different global tracking policies beneath energetically fluctuating conditions or indeterminate judgement clouds and taken as monetary constancy, quality guarantee type of obstacle as the serious components in the assortment process. AHP has already been given in literature as a favorable practice for selection of best manufacturing systems (Albayrakoglu 1996). AHP application in various field can be reviewed from the past literature (Vaidya et. al, 2006). This method is getting the popularity due to its simplicity and accuracy with unfettered judgement difficulties, particularly in conditions when quality concern in combination with different types of countable quantitative factors. The AHP is targeted for an integrated various procedures into a unique mark for ranking judgement substitutions.

The following are the steps in the AHP method for decision making:

1. The objective should be clearly defined.

2. Organization of hierarchy model from the upper level through the in-between level to the lowest level: It is very important because it helps to solve complicated, unstructured decision problems.

Formulate the appropriate hierarchy of AHP model consisting of goal, main factors and result. The goal of our problem is to justify the cellular manufacturing over lean and traditional manufacturing. This goal is placed on the first level of the hierarchy as shown in Figure 9.1. Seven major benefits, namely Improve net profit, improve productivity, waste reduction, improve quality, improve flexibility, inventory reduction and lead time reduction are identified to achieve this goal, which make the second level of hierarchy. The major benefits of Cellular manufacturing used in the second level of hierarchy can be assessed using the basic AHP approach of pair wise comparison of elements in each level with respect to every parent element located one level above. The third and last level consists of three alternatives, i.e., Cellular manufacturing, lean manufacturing and traditional manufacturing. AHP model is shown in Figure 9.1.

3 After building the AHP hierarchy, then the next step is to measurement and collection of data. It was done by a team of experts and assigning pair-wise comparison to the main factors used in the AHP hierarchy. The nine-point scale (Table 9.2) is used to assign relative scores to pair wise comparisons amongst the main factors. With the help of scale, experts assign a score to each comparison. Experts continue this process until all levels of the hierarchy and eventually a series of judgment matrices for the major factors were obtained. Team consisted of twelve experts, Out of these twelve experts; six were from industry, mainly from manufacturing sector such as automobile and main assembly line sectors and six from academic sector. Each one of them has more than seven year of experience in Cellular manufacturing area. A questionnaire consisting of all main factors of the two levels of AHP model is designed and is used to assemble the pair wise comparison judgment from all the experts. This process has been done until consensus made

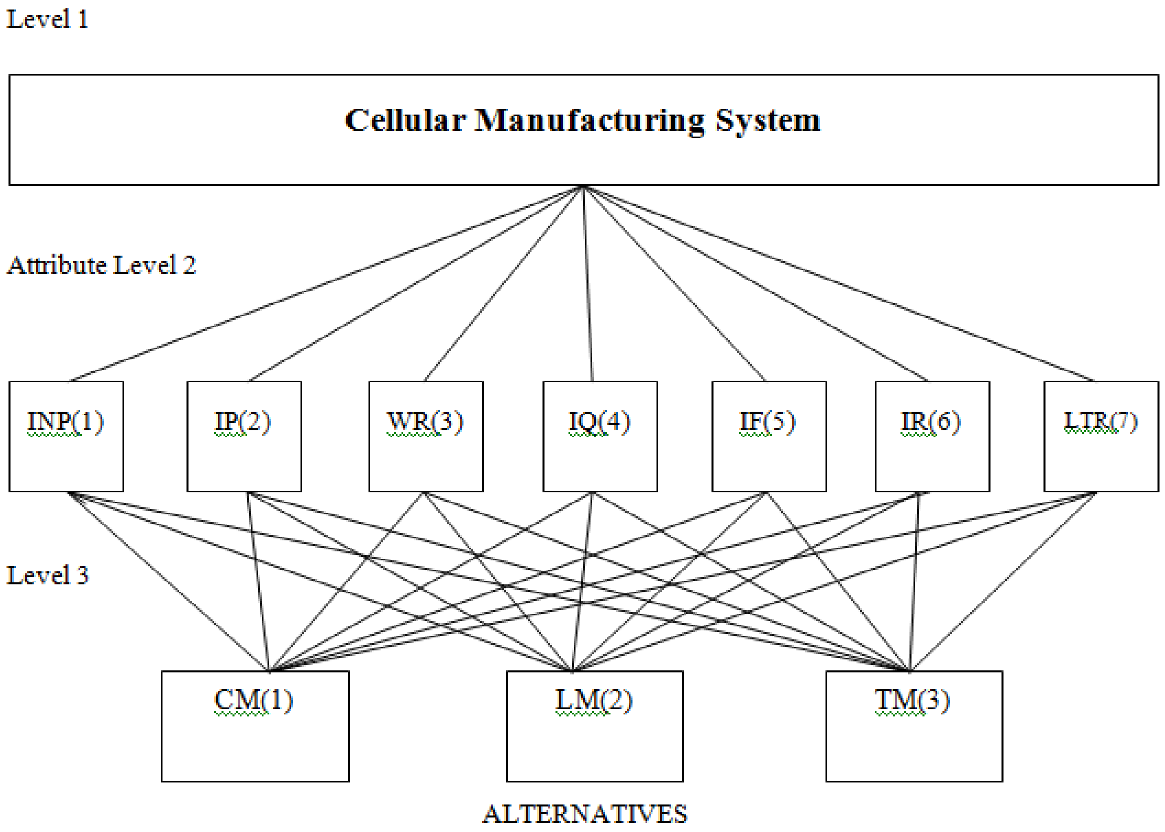

Figure: 9.1 AHP model

Table 9.1: Merits of CMS

S.NO.	Abbreviation	Benefits of CM
1	INP	Improve Net Profit
2	IP	Improve Productivity
3	WR	Waste Reduction
4	IQ	Improve Quality
5	IF	Improve Flexibility
6	IR	Inventory Reduction
7	LTR	Lead Time Reduction

9.2.2 Determine normalized weights

In order to find out the relative importance of seven major factors, then we make pair wise comparison judgment matrices with the help of expert's opinion, in the measurement and also data collection phase. For finding normalized weight, there are following Steps:

9.2.2.1 Construction of pair-wise comparison matrices

We make a set of pair-wise comparison matrices for each of lower levels attributes. An element, which is places at higher level is said to be a governing element which is placed in the lower level. Lower level elements are compared to each other based on their effect on the governing element at higher level. This yields a square matrix of judgments. We make pair-wise comparisons in such manner that one element dominate to other. Then these judgments expressed as integers. If element X dominates over Y, then the whole number integer is entered in row X, column Y and reciprocal is entered in row Y, column X If the elements being compared are equal, a one is assigned to both positions. Table 9.4 shows the pair-wise comparison matrix for level 2 criteria. There are n(n – 1)/ 2 judgments required to develop the set of matrices (reciprocal are automatically assigned in pair-wise comparison).

Table 9.2: Thomas Saaty's nine-point scale

Intensity of importance	Definition	Explanations
1	Equal Importance	Two activities contribute equally to the objective
3	Weak Importance one over another	Experience and judgment slightly favor one activity over another
5	Essential or Strong Importance	Experience and judgment strongly favor one activity over another
7	Demonstrated Importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Absolute Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgment	When compromise is needed
Reciprocals of above non-zero	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j* then *j* has the reciprocal value when compared with *i*	A reasonable assumption

9.2.2.2 To get the degree of consistency

It is common in the environment that society regularly remains unpredictable in particular situation of decisions, and thus one of the important tasks of AHP is to find out the consistency level of the estimated vector. In pair wise comparison, we use the Consistency ratio (CR) to measure the consistency level. Saaty (1990) gives the acceptable level of Consistency ratio (CR) for different matrices. For 3×3 matrix acceptable Consistency ratio (CR) is 0.05 and for 8×8 matrix is 0.08 and for large matrix is 0.1. If consistency level with in the acceptable range, then weight result is valid. When completed all the pair-wise comparisons and fill the data then the consistency is determined by using the eigen values. After that we normalize the columns by dividing each entry to the sum of all entries. After that we do sum of each row of the normalized values then take the average. This gives priority vector (PV). We check the consistency of judgments by following steps:

- Let the pair-wise comparison matrix is denoted by P1 and principal matrix is denoted by P2
- Then define P3 = P1 * P2; and P4 = P3 / P2
- $\lambda_{max.}$ = average of the elements of P4
- Consistency index (CI) = $\frac{(\lambda_{\max} - n)}{n-1}$
- Consistency ratio (CR) = CI / RCI corresponding to n.

Where RCI = Random Consistency Index and n = Numbers of elements (Table 9.3)

Table 9.3: Average RI standards

N	1	2	3	4	5	6	7
RCI	0	0	0.58	0.90	1.12	1.24	1.32

9.3 Results and discussion

When we make AHP hierarchy model, table 9.1 shows seven main factors which are considered for analysis. AHP model developed as shown in Figure 9.1 is used for justification of cellular manufacturing in SMEs. Then we make pair-wise comparison judgment matrices to find out the normalized weight. Pair wise criteria comparison matrix shown in table 9.5, this table shows all the seven major benefits of cellular manufacturing. After that we calculate the CR value to check the degree of consistency. The degree of consistency of the pair wise comparison matrix and CR for level 1 is shown in table 9.5. Then we follow same procedure to find the PV and CR for other levels. Then table 9.6 shows the results. We observed from table 9.6 that all seven factors of cellular manufacturing have more PV in comparison to traditional manufacturing. We also examined that CR value is less than 0.1 for all decision factors. Local weight of attributes for alternatives shows in table 9.7. Global weight of major benefits for cellular manufacturing shown in table 9.8. Global weights have been calculated by following method:

Individual weight of the main factor = P.V. value from the respective normalized table

Individual weight of the sub factor = P.V. value from the respective normalized table

Global weight of main factor = individual weight of that main factor

Similarly, global weights for other strategic factors and sub factors can be calculated:

Global Wt. of cellular manufacturing (CM) = Level 2 Wt. × CM Wt.

Global Wt. of lean manufacturing (LM) = Level 2 Wt. × LM Wt.

Global Wt. of traditional manufacturing (TM) = Level 2 Wt. × TM Wt.

Total global Wt. = sum of the global wt. of respective column.

Out of seven major benefits of cellular manufacturing, lead time reduction has highest global weight (0.7637). Minimum lead time is required to obtain maximum profit because lead time decrease production increase. Second highest global weight is to increase productivity (0.7526). If productivity increased then net profit increase. So we increase the productivity in such a manner that overall cost of operation decrease. Waste reduction is the third benefit of cellular manufacturing whose global weight is 0.7402. With the help of cellular manufacturing we eliminate non value added process so that our wastage is reduced. Fourth highest global weight is improves quality (0.7024). With the help of cellular manufacturing, quality of product increased because we use standard process to make a product. Improve flexibility has fifth highest global weight whose global weight is (0.6408). If flexibility increases in production system then our profit increased. Six benefit of cellular manufacturing is inventory reduction and its global weight is 0.6408. With the help of cellular manufacturing, raw material and work in process inventory decreased because of standard process of CMS. Next benefit of cellular manufacturing is increased net profit. When cellular manufacturing used then production increased, inventory decreased, waste decrease, lead time decrease, increase flexibility and improve quality. So that effect of these factors our net profit increased. Global suitability index of cellular manufacturing and traditional manufacturing shown in table 9.9.Global suitability index of cellular manufacturing is 0.7254 and lean manufacturing is 0.2054 and traditional manufacturing is 0.0690. So this analysis shows that application of cellular manufacturing is better than lean and traditional manufacturing.

Table 9.4: Criteria pair wise comparison matrix (level 2)

	INP	IP	WR	IQ	IF	IR	LTR	P.V
INP	1	1/9	1/5	1/5	1/8	1/4	1/9	0.02025
IP	9	1	6	5	3	6	1/4	0.24732
WR	5	1/6	1	1/3	1/5	2	1/7	0.05556
IQ	5	1/5	3	1	1/4	3	1/4	0.08907
IF	8	1/3	5	4	1	4	1/3	0.16908
IR	4	1/6	½	1/3	1/4	1	1/8	0.04279
LTR	9	4	7	4	3	8	1	0.37591

The procedure to normalize the benefits and to find the CR value is as follows.

Let P_1 is pair wise comparison matrix

P_2 is principal vector matrix

$$P_2 = \left\{\begin{matrix} 0.02025 \\ 0.24732 \\ 0.05556 \\ 0.08907 \\ 0.16909 \\ 0.0428 \\ 0.37591 \end{matrix}\right\}$$

Then $P_3 = P_2 \times P_1$

$$P_3 = \left\{\begin{matrix} 0.1502595 \\ 2.0663064 \\ 0.4008324 \\ 0.671103 \\ 1.3440995 \\ 0.3117478 \\ 3.142288 \end{matrix}\right\}$$

$P_4 = P_3/P_2$

$$P_4 = \left\{ \begin{matrix} 7.420271 \\ 8.35473 \\ 7.214518 \\ 7.534481 \\ 7.949064 \\ 7.284357 \\ 8.359096 \end{matrix} \right\}$$

Component Average of P_4 ($\lambda_{max.}$) = 7.7309308

Now consistency index (CI) = $\dfrac{(\lambda_{\max} - n)}{n-1}$ = 0.121822

And consistency ratio (CR) = CI / RCI =0.092289

So CR is less than 0.1, result is consistent.

Table 9.5: Consistency ratio of comparison matrix

CR	0.092289

Table 9.6: Pair wise association judgment matrices for Alternatives

Alternative analysis with respect to [INP]				
	CM	LM	TM	P.V.
CM	1	3	6	0.6285
LM	0.33	1	5	0.2921
TM	0.16	0.2	1	0.0794
TOTAL	1.49	4.2	12	CR<0.1

Alternative analysis with respect to [IP]				
	CM	LM	TM	P.V.
CM	1	6	9	0.7526
LM	0.16	1	4	0.1832
TM	0.11	0.25	1	0.0641
TOTAL	1.27	7.25	14	CR<0.1
Alternative analysis with respect to [WR]				
	CM	LM	TM	P.V.
CM	1	6	9	0.7402
LM	0.16	1	5	0.1994
TM	0.11	0.2	1	0.0603
TOTAL	1.27	7.2	15	CR<0.1
Alternative analysis with respect to [IQ]				
	CM	LM	TM	P.V.
CM	1	4	8	0.7024
LM	0.25	1	4	0.2269
TM	0.12	0.25	1	0.0707
TOTAL	1.37	5.25	13	CR<0.1
Alternative analysis with respect to [IF]				
	CM	LM	TM	P.V.
CM	1	3	6	0.6408
LM	0.33	1	4	0.2735
TM	0.16	0.25	1	0.0857
TOTAL	1.49	4.25	11	CR<0.1
Alternative analysis with respect to [IR]				
	CM	LM	TM	P.V.
CM	1	3	6	0.6408
LM	0.33	1	4	0.2735
TM	0.16	0.25	1	0.0857
TOTAL	1.49	4.25	11	CR<0.1
Alternative analysis with respect to [LTR]				
	CM	LM	TM	P.V.
CM	1	7	9	0.7638
LM	0.14	1	4	0.173
TM	0.11	0.25	1	0.0632
TOTAL	1.25	8.25	14	CR<0.1

Table 9.7: Attributes weights

ATTRIBUTES WEIGHTS					
S.NO.	Attributes	Wt. P. V.	C.M. P.V.	L.M. P.V.	T.M. P.V.
1	INP	0.020249861	0.628475551	0.292079472	0.079445
2	IP	0.247321748	0.752614975	0.183209857	0.064175
3	WR	0.055559139	0.740244969	0.199402158	0.060353
4	IQ	0.089070906	0.702405462	0.226883417	0.070711
5	IF	0.169089039	0.640825946	0.273468997	0.085705
6	IR	0.042796887	0.640825946	0.273468997	0.085705
7	LTR	0.37591242	0.763780664	0.172975469	0.063244

Table 9.8: Suitability index table of alternatives global weight

GLOBAL WEIGHT OF ALTERNATIVES				
S.NO.	Attributes	CM GLOBAL WT.	LM GLOBAL WT.	TM GLOBAL WT.
1	INP	0.012726543	0.005914569	0.00160875
2	IP	0.186138051	0.045311782	0.015871915
3	WR	0.041127373	0.011078612	0.003353154
4	IQ	0.062563891	0.020208711	0.006298304
5	IF	0.108356643	0.04624061	0.014491786
6	IR	0.027425356	0.011703622	0.00366791
7	LTR	0.287114638	0.065023627	0.023774155

Table 9.9: Global Suitability index of replacements

GLOBAL SUITABILITY INDEX OF CMS	0.725452
GLOBAL SUITABILITY INDEX OF FMS	0.205482
GLOBAL SUITABILITY INDEX OF TMS	0.069066

9.4 Conclusion

The AHP results provide strategic insight also. It is also observed from the table 9.9 that Global suitability index of cellular manufacturing has find the highest value converting this method to be most suitable for the production in competitive area with continuous ever changing demands. Traditional manufacturing system got the minimum value for suitability index providing it to be lesser suitable for best production in the above said area. So, the management of companies should first of all do the introspection and commit itself to accept this universally accepted and challenging technology for acquiring a better place in the market. This study has strong implications for researchers as well as manufacturing managers. The researchers may be prompted to identify some other issues, which may be significant in addressing these indexes. The manufacturing managers can get an insight of these suitability factors and understand their relative importance and interdependencies and try to overcome the drawback in a successful transition to CMS. Executives in the era of production industries may conclude perceptions from the realistic study presented in this paper. The managers should have clear visualized the benefits of CMS. The managers should plan an effective strategy for proper linkage of human element with high technology of CMS.

The major contribution of the present work is to present the current status of production system in the dynamic environment. Above analysis shows that cellular manufacturing is better than Lean manufacturing and traditional manufacturing. Global Suitability index of cellular manufacturing is 0.681985 and global Suitability index of lean manufacturing and traditional manufacturing are 0.242248 and 0.075766 respectively. Hence the obtained global Suitability index of cellular manufacturing is higher than other two manufacturing systems making it as a best manufacturing system among the above.

The findings of this research would be useful to managers involved in CMS transition process. They need to focus more on these attributes, which will help in transforming the production system. On the other hand, only focusing on these attributes will not help the management of those attributes having high importance. As a part of future research, more attributes may be included in the AHP. The future scope of this study for researchers is to make this application easier. For this purpose, it is concluded here to

- Study of collective associations of CMS applications
- Study of replacement production system other than FMS systems in the policy and improvement of CMS
- Identification of different variables affecting machine and product flexibility of CMS.

CHAPTER 10

SELECTION OF BEST MANUFACTURING SYSTEM USING AHP TECHNIQUE

10.1 INTRODUCTION

Analytic hierarchy process is used for finding the optimal solution among the available alternatives. AHP is becoming more and more popular from its simplicity and ease of use with suitable accuracy. AHP is synthesized in various sectors in India to get the benefit of this multi criteria decision method like in education sector, manufacturing industries, automobiles sector and in public health factors. Now a day this technique is dominating over various available MCDM methods. In this chapter manufacturing alternatives has been selected as main criteria and then sub attributes of those criteria's are selected with the brainstorming and with the expert opinion and suggestions. Technique is synthesized to get the best manufacturing system among the considered manufacturing systems.

10.2 OVERVIEW OF AHP

Saaty (1980) illustrated a multi criteria decision method Analytic Hierarchy Process which is the best method to identify and for rankings of various complexes inter related attributes. Where "logical" elements show that the objective or difficulty is divided into its native attributes and sub attributes. The hierarchy of the system comprises the fundamental points to be combined in context of the foremost target. The AHP now a day is commonly used in various decision techniques such as in education sector, manufacturing sector, and automobile sector etc. AHP is the best suitable method for conflicting decisions. The method is suggested a model for multi-attribute utilization attitude to calculate different global tracking policies beneath energetically fluctuating conditions or indeterminate judgement clouds and taken as monetary constancy, quality guarantee type of obstacle as the serious components in the assortment process. AHP has already been given in literature as a favorable practice for selection of best manufacturing systems (Albayrakoglu 1996). AHP application in various field can be reviewed from the past literature (Vaidya et. al, 2006). This method is getting the popularity due to its simplicity and accuracy with unfettered judgment difficulties, particularly in conditions when quality concern in combination with different types of countable quantitative factors. The AHP is targeted for an integrated various procedures into a unique mark for ranking judgment substitutions.

10.2.1 Procedure of AHP technique:

- The objective should be clearly defined.
- Organization of hierarchy model from the upper level through the in-between level to the lowest level: It is very important because it helps to solve complicated, unstructured decision problems.
- Pair wise comparisons among n elements in each level: Pair wise comparisons of the criteria and alternatives based on the Saaty's scale of numbers from 1 to 9, shown in table 10.1 .The value 1 stands for equal importance of two criteria (alternatives), while the value 9 is for extreme importance of one criterion (alternative) to another. Pair wise comparisons of the criteria are executed with respect to the aim or criteria at higher level. The weights of the criteria gives the ratio of how much more important is one criterion over other, with respect to the goal or criterion at higher level. Pair wise comparisons of the alternatives are performed against each criterion.

Table 10.1 Scale of preferences between two components

S.N	Decision	Degree of preference
1	Equally important	I
2	Slightly important	III
3	Highly important	V
4	Very highly important	VII
5	Extremely important	IX

Note: Transitional levels (2, 4, 6, and 8) are synthesized to get supplementary levels of judgement

- Consistency is checked for pair wise assessment. Saaty (1980) has elaborated the highest eigenvalue, λ, of a mutual matrix A is ever more than or equal to n. If the pair wise evaluations do not include any discrepancies, λ = n. The more coherent the maximum evaluations are, the nearest the value of computed λ to n. CI can be derived by the nonconformity of pair wise comparisons, is given as:

$CI = , \lambda - n / n-1$

where λ is an eigenvalue of matrix A.

A Consistency Ratio (CR) is given by:

CR= 100 [CI / RI]

where:

CI=Consistency index

RI = Random index

N= Number of columns

If CI is adequately low, the expert judgements are almost certainly persistent to provide convenient predictions of the masses for the equitable purpose. If CI/RI < 0.10, the grade of persistency is tolerable, but if CI/RI > 0.10, potential variations may exist, and the AHP may not give the satisfactory results (Alviet et. al., 2001).

- If the CI and CR are found acceptable, then the judgement is taken based on the normalized values; else the method is conducted again till these values found in the expected range.

10.3 Calculation of consistency ratio:

The pair-wise judgements of the standards for assortment of production system problem generate a matrix of absolute rankings for every level of the hierarchy. The number of matrices depends on the number of components at each level. The order of each matrix of consecutive top level is formulated by the number of elements at respective level. After all the matrices formulation, eigenvectors or the relative weights (the degree of relative importance amongst the elements) and the maximum eigen value (λ_{max}) for each matrix are derived. The λ_{max} value is an important validating parameter in AHP. It is used for calculating the consistency ratio (CR) (Saaty, 2000) of the projected vector in order to authenticate whether the pair-wise comparison matrix delivers an absolutely consistent evaluation. Table 10.2 shows the value of the Random Consistency Index (RI) for matrices of order 1 to 10 obtained by approximating random indices using a sample size of 500 (Saaty 2000).

Table 10.2: RI based on Matrix Size

S. No.	n	RI
1	I	0
2	II	0
3	III	0.52
4	IV	0.89
5	V	1.11
6	VI	1.25
7	VII	1.35
8	VIII	1.40
9	IX	1.45
10	X	1.49

The allowable CR range differs along with the size of matrix i.e. 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all bigger matrices, n>= 5 (Saaty 2000) . If the value of CR is equal to, or less than that value, it shows that the estimation within the matrix is allowed or represents a good level of consistency in the comparative judgments represented in that matrix.

10.4 Strength and weakness of AHP technique:

The strength and weakness of AHP technique are as follows:

Strength :

- Provides a formal multi-attribute judgement-making mechanism for ranking the factors
- The methods to make the hierarchy are quite simple and easily

- The decision problem is presented as graphical hierarchical structures which may results potential risk

Weakness:

- Customers can have problems to deal with a number of reasons which products into inconsistency for giving the valuation of the importance between the issues. In particular cases the ranking of the substitutes can be reversed when a new alternative is developed.
- The fuzziness present in many judgement-taking complications may results into the indefinite decision of expert.

10.5 AHP Model:

In this chapter, the main objective is to select the best manufacturing system. This goal is placed at the top level of hierarchy. Three strategic factors, namely cellularity, cost and flexibility have been identified to achieve this goal. These three factors form the second level of hierarchy. The third level of the hierarchy consists of the criteria defining the three strategic factors. There are two criteria related to cellularity, namely modularity and scalability, three criteria related to cost, namely raw material cost, process cost, indirect cost, two criteria related to flexibility namely machine flexibility, product flexibility.

The fourth i.e., the lowest level of hierarchy consists of different alternatives, namely dedicated manufacturing system, flexible manufacturing system, reconfigurable manufacturing system. The structure of the hierarchy is as shown in Figure 10.1.

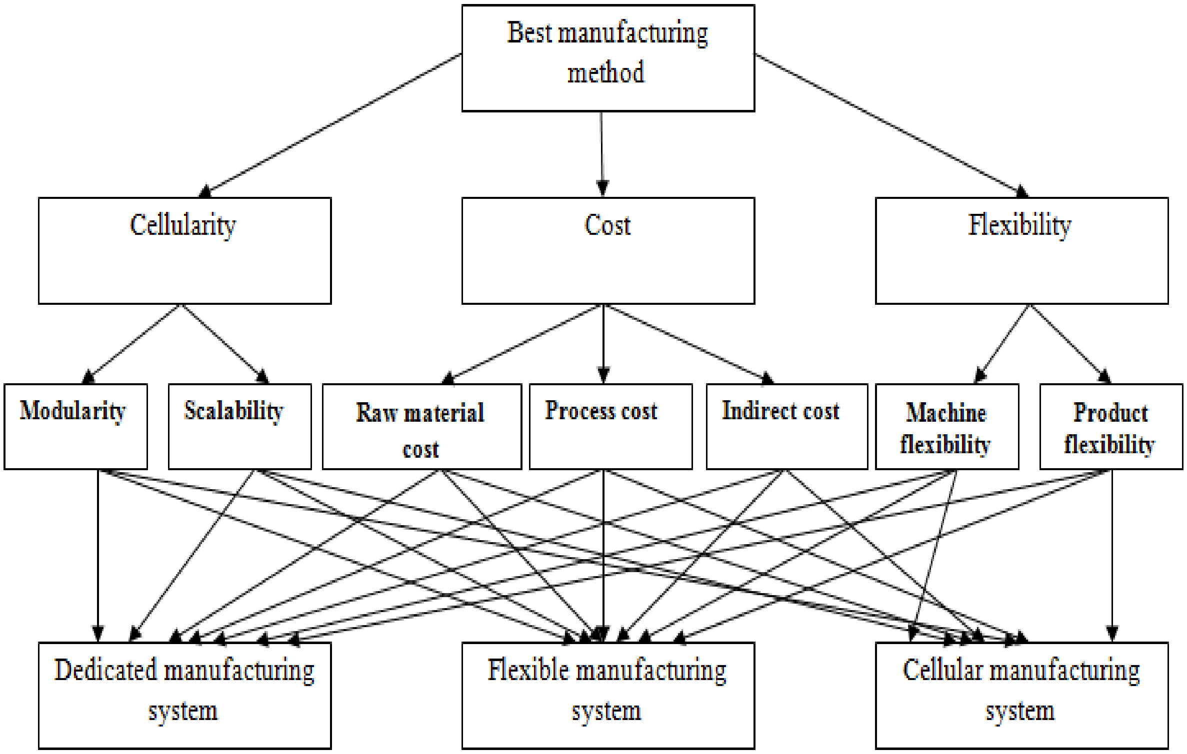

Fig 10.1: Analytic hierarchy structure of manufacturing system

In the following section the main three attributes and their relative criteria are discussed:

(A) Cellularity:

A subset of flexibility in which production set up can be changed repeatedly and reversibly. In other words the cellularity is the ability to repeatedly change and rearrange the components of a system in cost effective way. The following two criteria related to cellularity are considered as follows.

(A_1) Modularity: In the cellular manufacturing system the major components must be modular. It is an approach for mass flexibility, in such a method modules comprising a system can be replaced and updated. The benefit of modularity is increased feasibility, reduced lead time and reduced maintenance repair.

(A_2) Scalability: It is the tendency to regulate the production capacity (volume) of a manufacturing organization with minimum cost and in minimum time over a wide variety of products. Designing manufacturing systems with the characteristics of production scalability allows management to increase and decrease production capacity quickly and cost effectively in response to market demand (Azzone et. al., 1989).

(B) Cost: Operating cost is the kind of a cost required to run the plant efficiently. Operating cost usually varies with the volume of production and is often estimated as a multiple factor of the direct labor cost. This attribute is evaluated based on the following criteria:

(B_1) Raw material cost: It represents the cost of different raw material i.e., bar cost and fixtures used in different production lines. Cost of raw material is comparatively lower in conventional production lines in comparison to RMSs.

(B_2) Process cost: It represents the cost of process. If processing of material is not adequate, then more scrap will be produced and more money is wasted as scrap cost.

($B_{3)}$ Indirect cost. It represents the cost of trainees. Cost of maintenance of different machine tools and equipment's.

(C) Flexibility : The flexibility of a manufacturing system can be defined as the ability of the system to respond to changes either in the environment or in the system itself (Raj et al 2007). Manufacturers of discrete parts face increasing demands for small-to-medium sized lots of customized products, requiring a production process, which can provide flexibility as well as economy (Ayag 2002). Technological developments and market demands are forcing the organizations towards more flexibility. As a result, process flexibility is fast becoming a major priority for many organizations. The following two criteria related to flexibility are considered as follows.

(C_1) Machine flexibility: means various operations performed without set up change. The machine flexibility is very important.

($C_{2)}$ Product flexibility : Ease (time and cost) of introducing parts in to an existing product mix. It contributes to agility. Product flexibility indicates the ease by which new products can be introduced in a firm. This type of flexibility is higher in a product layout if the new product can be assigned to a single existing product group (quicker response).

If a new product has impact on the design of the manufacturing cells, then a process layout is more stable and has more product flexibility (larger range).

10.6 Dedicated manufacturing system (DMS):

The dedicated manufacturing lines or transfer lines represent a sequential, series of machines used to manufacture a single specific product. Transfer lines may be characterized by a few salient features: a) dedicated transfer equipment, b) low cost per part when demand exceeds supply, and c) high production volume.

10.7 Flexible manufacturing system (FMS):

Flexible manufacturing systems were created in the 1960’s to achieve a wider variety of production capabilities than traditional dedicated transfer lines. FMSs combine the repeatability of transfer lines with the flexibility of computer numerical control (CNC) machines In general, FMSs achieve flexibility through the use of programmable software architecture to quickly change work orders and process sequences. Due to this low throughput and the high cost of CNC machines, the FMS fails to deliver an acceptable cost per part. To satisfy the shortcomings of FMSs, reconfigurable manufacturing systems were proposed to deal with the volatile, uncertain market conditions and cost per part requirements of consumers.

10.8 Cellular Manufacturing Systems (CMS):

In today’s competitive environment many companies are motivating to improve their manufacturing performance. It is now universally accepted that cellular manufacturing is one such method that manufacturers can use to help meet their goals, through product and production flexibility, lower costs and improved customer response times. Furthermore, the implementation of Cellular Manufacturing has been shown to achieve significant improvements in product quality, space utilization, and control of operations, scheduling, and employee morale (Huber & Brown, 1991; Wemmerlov & Johnson, 1997; Park &Han, 2002). This implies that Cellular Manufacturing Systems should not only possess the necessary flexibility to manufacture a large variety of parts, but also be able to achieve high throughput. A Cellular Manufacturing System may be optimized for cost effectiveness for a certain variety of parts.

10.9 Priority weights for different levels:

In this section, priority weights of different attributes and those of different alternatives with respect to different sub-attributes are determined. The pair-wise comparison of different attributes is depicted as a matrix in Table 10.3. As cellularity is considered to be more important than other attributes, its value has been decided as five times that of flexibility, three times against cost. Cost is considered to be more important than flexibility and cellularity. The pair-wise comparison matrix is normalized by dividing each value by the sum of the corresponding column. Finally, the CR is calculated as 0.074, which is found to be consistent (as this value is less than 0.10).

Table 10.3 Investigation of attributes

	Pair wise comparison			Normalization			
	Cellularity	cost	flexibility	cellularity	cost	flexibility	weights
Cellularity	1	3	5	0.652	0.94	0.5	0.627
Cost	1/3	1	4	0.217	0.235	0.4	0.280
Flexibility	1/5	1/4	1	0.1304	0.58	0.1	0.094

Max. Eigenvalue = 3.086

Consistency ratio = 0.074

The next step is to examine the effect of level III elements on the respective elements of level II. The same procedure is adopted as discussed in the above paragraph and Table 10.4 represents the analysis of sub-attributes on cellularity. Similarly, analysis of different sub-attributes on other attributes is done and weights of all sub-attributes are represented in the second column (M) of Table 10.12

Table 10.4 Investigation of sub-attributes of Flexibility

Pair wise comparison			Normalization		
	Modularity	Scalability	Modularity	Scalability	weights
Modularity	1	2	0.66	0.66	0.667
Scalability	1/2	1	0.33	0.33	0.333

Max. Eigenvalue = 2.06

Consistency ratio = 0.000

The analysis of the pair-wise matrix of different alternatives (such as dedicated manufacturing, flexible manufacturing, and cellular manufacturing system) with respect to modularity is represented in Table 10.5. Similarly, the analysis of the pair-wise matrices of different alternatives with respect to all other sub-attributes is done and their respective weights are represented in Table 10.12. A careful approach has been adopted in the pair-wise comparison of different alternatives. Form analysis it clearly shows that the alternative cellular manufacturing system is more important than the alternative dedicated manufacturing and flexible manufacturing. The significance level of different alternatives has been considered as follows:

Alternative (DMS) < Alternative (FMS) < Alternative (CMS)

Table 10.12 represents the data from all the pair-wise matrices. From this data, the suitability index is calculated and the alternative with the highest suitability index is selected as the best manufacturing system.

Table 10.5 Investigation of alternative w.r.t Modularity

Pair wise comparison				Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	2	1/3	0.230	0.4	0.181	0.263
FMS	1/3	1	½	0.766	0.2	0.272	0.190
CMS	3	2	1	0.69	0.4	0.545	0.547

Max. Eigenvalue = 3.117

Consistency ratio = 0.087

Table 10.6 Investigation of alternative w.r.t Scalability

Pair wise comparison				Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	3	1/2	0.300	0.426	0.273	0.033
FMS	1/3	1	1/3	0.1	0.142	0.182	0.140
CMS	2	3	1	0.60	0.426	0.546	0.528

Max. Eigenvalue = 3.0536

Consistency ratio = 0.0462

Table 10.7 Investigation of alternative w.r.t Raw material cost

Pair wise comparison				Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	1/2	1/3	0.166	0.426	0.273	0.151
FMS	2	1	1/4	0.1	0.181	0.182	0.218
CMS	3	4	1	0.60	0.426	0.631	0.630

Max. Eigenvalue = 3.105

Consistency ratio = 0.0930

Table 10.8 Investigation of alternative w.r.t process cost

Pair wise comparison				Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	1/4	1/5	0.1	0.076	0.117	0.097
FMS	4	1	1/2	0.4	0.307	0.294	0.333
CMS	5	2	1	0.5	0.614	0.588	0.570

Max. Eigenvalue = 3.0246

Consistency ratio = 0.0212

Table 10.9 Investigation of alternative w.r.t indirect cost

Pair wise comparison				Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	1/3	1/5	0.111	0.1	0.117	0.109
FMS	3	1	1/2	0.333	0.3	0.294	0.309
CMS	5	2	1	0.555	0.6	0.588	0.582

Max. Eigenvalue = 3.0037

Consistency ratio = 0.0032

Table 10.10 Investigation of alternative w.r.t machine flexibility

Pair wise comparison				Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	1/5	1/3	0.111	0.0384	0.210	0.107
FMS	5	1	1/4	0.555	0.192	0.157	0.286
CMS	3	4	1	0.333	0.048	0.631	0.607

Max. Eigenvalue = 3.4134

Consistency ratio = 0.0352

Table 10.11 Investigation of alternative w.r.t product flexibility

	Pair wise comparison			Normalization			
	DMS	FMS	CMS	DMS	FMS	CMS	weights
DMS	1	1/4	1/3	0.125	0.076	0.181	0.124
FMS	4	1	1/2	0.5	0.307	0.272	0.359
CMS	3	2	1	0.375	0.615	0.545	0.517

Max. Eigenvalue = 3.1078

Consistency ratio = 0.0930

Table 10.12 Calculation of suitability index

Weights of Sub attributes	**weights of** attributes	**Weight of different alternatives**			**(M) x (N) X** weight of different alternatives		
M	N	DMS	FMS	CMS	DMS	FMS	CMS
0.66	0.627	0.263	0.190	0.547	0.1088	0.0784	0.225
0.33	0.627	0.033	0.140	0.528	0.006	0.028	0.109
0.630	0.280	0.151	0.218	0.630	0.0266	0.039	0.111
0.151	0.280	0.097	0.333	0.570	0.004	0.014	0.024
0.218	0.280	0.109	0.309	0.582	0.006	0.018	0.034
0.333	0.094	0.107	0.286	0.607	0.003	0.008	0.019
0.667	0.094	0.124	0.359	0.517	0.007	0.022	0.032
Suitability indices of different alternative					0.161	0.2074	0.554

The suitability index for each alternative is calculated by multiplying each value in column (M) by the respective value in column (N), and then by multiplying the value for each alternative and summing the results (Table 10.12). The suitability index of alternative CMS is the highest (0.5554) and should be selected as the best manufacturing system given the criteria in this paper. This alternative offers more benefits than other alternatives such as the highest modularity, scalability, high flexibility.

10.10 Conclusion:

This chapter develops an AHP model for selection of best manufacturing method. The AHP model is proposed to take into account both qualitative and qualitative criteria of cellularity, cost and flexibility. Flexibility is the most sought after property in any manufacturing system today and this can be ensured through the adaptation of CMS. Many companies want to adopt CMS but biggest problem for them is to switch over. Top management of the companies does not want to take any risk. Hence for the satisfaction of top managers, selection of CMS has been shown by AHP in this paper which is a very good tool for decision making in such cases. The present work is useful for the adoption of CMS but following issues are required to be resolved for the fool proof implementation of CMS:

Issues related to measurement of flexibility in CMS

Issue of use of advanced material handling systems in CMS

Study of social issues of adoption of CMS

Study related to the Issue of productivity with the adoption of CMS

CHAPTER 11

FACTORS AFFECTING IMPLEMENTATION OF CMS USING GRAPH THEORETIC APPROACH

11.1 INTRODUCTION

"Cellular manufacturing" is a practice of manufacturing set up in which there is combination of batch production and product manufacturing incorporating group technique type of production. The main aim of "cellular manufacturing" is to react as fast as imaginable, by making a broad range of similar type of parts, while making as little as scrap as imaginable (Datta et.al. 1992). The requirements of customer are changing frequently in nature enforces to make a strong need for a newer technique of manufacturing systems. For getting the adequate competency and to remain in survival with highly dynamic markets, Industries should have minimum flexibility to respond over a range of products to produce on the shop floor (Singh et al., 2010). As from above it may conclude, cellular manufacturing systems are the systems that can be adopted to get the production with economic aspects as well as manufacturing concerns; to ensure the existence in the competitive and dynamic environment (Abdul et al 1999). Cellular manufacturing systems (CMSs) are the type of manufacturing system which is used to produce different product families based on similarity of operations in the minimum time with different machine cells based on similar processing at the minimum possible cost without negotiating with the quality of the product (Biswas et. al., 2017). The quantitative analysis of factors has been done by graph theory method. It is a systematic and logical approach. Graph model representation has proved to be useful for modelling and analysing various kinds of systems and problems in numerous fields of science and technology (Rao and Padmanabhan, 2008). The matrix approach is useful in analyzing the graph models expeditiously to derive the system function and index to meet the objectives. Moreover, representation of the graph by a matrix offers ease in computer handling. In view of these, graph theory and matrix methods are proposed in this paper for the quantification of factors of cellular manufacturing systems. Through literature survey, it was found that a good amount of work was devoted in identifying factors affecting the design and implementation of cellular manufacturing systems. However, most of the available literature considered different factors as an independent entity affecting the CMS implementation and they did not discuss the interaction of one factor to another factor. But the extent to which one factor is present may affect the other factor. In this paper, an attempt was made to analyze and quantify these factors using digraph and matrix approach. The main objectives of this paper are as follows:

- To identify and segregate the factors into different categories through literature study and experts' opinion
- To propose a single numerical index representing the value of the multinomial of the model.

11.2 Identification and segregation of factors

From the past literature review and discussions with experts and academicians, number of factors were identified, affecting CMS implementation in industries. As the number of these factors affecting the design and implementation of CMS is large, it becomes very difficult to compute their quantification by graph theoretic approach (GTA). These factors are grouped into different categories so that their permanent value (function) can be calculated without much difficulty. If large numbers of factors are taken as it is or if they are grouped into large number of categories, then, this calculation will become highly complex and difficult. Hence, they are grouped into five major categories. Through literature survey, it was noticed that similar categorization of factors was done by some researchers. Taking inspiration from the work of these authors; factors are grouped into the following five categories in the present study:

11.2.1 Technical factors

Technical factors are those factors of manufacturing system that are related with men, machine, methods, and tools in an organization. This category includes the following factors

- Improve productivity
- Increase automation

- Customer relationship management
- Organizational structure
- Men power utilization
- Consolidation of information

Nowadays, the manufacturers are continuously seeking ways and measures to gain competitive advantages. As competition intensifies, they have to enhance their manufacturing flexibility, quality, and costs. Consequently they have become more and more open to new and innovative ideas that are perpetuated to yield competitive gains to increase the productivity (Dixit et. al., 2013). Improved production can only ensure the stability of particular manufacturer in the highly competitive market. The productivity can be achieved only with the use of increased automation. Thus automation in the production is important tool to enhance productivity without scarifying with the quality of the product (Kumar et. al., 2017). However, cellular manufacturing system will not only have the ability to add whole machines in parallel, but will also have new designs and development of machine tools to get the required target with adequate flexibility.

This means that machine modules can be added to the individual machines to change capacity more rapidly. According to Fricke the flexibility may be defined as the ability to change and adapt to a range of states. The word flexibility comes from the Latin language, meaning ‘to blend’. Flexibility is an important factor undertaking towards the conceptual understanding of cellular system design. Automation is a critical factor in estimating the performance of any type of manufacturing system. Automation is a main revolutionary force in the success of any organization. It is a potential factor of cellular manufacturing system because the utilization of man power up to maximum extent is the key to the success of an industry. A cellular manufacturing company is required to provide its customers with products that would require little or no service. In this regard, the concept of flexible design is brought to the attention of the researchers (Zhang 2011). So that, PSM is the appropriate factor in flexible manufacturing environment *i.e.* to either eliminate or reduce the duration of product’s service. This factor will drive the manufacturer to improve the reliability of the products and strengthen the company’s flexible capabilities.

From the long time structure of management has been found in such a way that its impact on shop floor workers and staff is very low (Malhotra 2014). Organizations that are having flat hierarchy provide a concept of activities of management; increase in coordination, less administration, better infrastructures, and support from workers. Management support with clear organization structure always aids in application of cellular manufacturing system. To attain the maximum productivity effective planning with optimum utilization of resources mainly the available men power has to be done. The consolidation of information plays a very important role in integration of different manufacturing industries. Information technologies integrate the industries after reengineering the existing system. The task that are not to be supported by paper work are to be removed and then to be integrated using information technology (Gunasekaran et. al., 2008). So for successfully accomplishment of cellular manufacturing information technology plays a very dominant role.

11.2.2 Behavioral factors

These factors are related to the people who are interacting with the organization. The success of the CMS implementation is dependent on the behavior of human resources, viz. employer and employee, customer and supplier. They are the ones who raise the organization to newer heights in a competitive scenario. The behavioral factors are as follows:

- Technology information
- Development of design
- Flexible workforce
- Top management support
- Empowered workers

This technology information has role in integration of different manufacturing industries. Information technologies integrate the industries after reengineering the existing system. The task that are not to be supported by paper work are to be removed and then to be integrated using information technology (Gunasekaran et al., 2008). So for successfully accomplishment of cellular manufacturing information technology plays a very dominant role.

During designing process, it is very necessary that team member should be assigned full time. As far as possible, the team should be co-located together at an assigned location to facilitate working together (Sethi and Kota 2009). It is very necessary that the team should be familiar with the business functions and products so they know what needs to be done to support major business processes.

According to Kumar et. al., 2015 the management should have clear vision about the implementation of cellular manufacturing system and should prepare the long term plan for it. In order to succeed, there must be a substantial commitment on the part of top management in any organization (Raj 2010). The purpose must be clearly and continuously communicated to all personnel. Both business philosophy and the top management's personal philosophy work together in forming the operational guidelines of the firm (Holland et. al., 1999).

11.2.3 Non Behavioral factors

Non-behavioural factors play a key role in implementation of cellular manufacturing system. This category of factors includes the following:

- On time delivery
- Available floor area
- Availability of resources
- Customer satisfaction

According to (kumar et. al., 2018), the availability of resources, i.e., man, machine, material, etc., are must for accomplishment for task. Hence, careful and intelligent allocation of resources is to be done so that desired output could be achieved on time delivery with minimum consumption of resources. Software is tangible whereas hardware is intangible factors and they are required for up gradation.

These factors are important in implementation of CMS. According to Davenport (2008), operational technique includes all the activities that establish a structure of task and authority so that operations are performed in accordance while controlling techniques are the feedback devices to check whether the job is carried out as per plan or not. These techniques are very helpful in implementation of CMS. Good working space, job security, a fair and free work space environment provide job satisfaction to an employee. Absence of these may also act as dissatisfaction.

11.2.4 Strategic factors

These factors are related to poor strategic planning of the company. Strategic planning is imperative as it provides a framework for proactive decision making to evaluate performance continuously and also to assess what could go wrong, determine significant risks and implement strategies to deal with those risks. Strategic factors are as follows:

- Advanced technology
- Quality
- Service
- Flexibility
- Vendor development

Quality in an organization develops the competency and level of faith in the mind of customers. To satisfy the customer's quality standards must be followed by the manufacturer (Malhotra 2014). Quality policies are framed to develop better working environment for the workers as well as the end users of the product. Quality and productivity can be handled simultaneously when the advanced technology is adopted in the manufacturing system. Vendor development can be defined as any activity that a buying firm undertakes to improve a supplier's performance and capabilities to meet the buying firms' supply needs (Lander and Minko, 2001). Therefore, the vendor development factor plays important role in designing of cellular manufacturing.

11.2.5 Financial factors

Financial factors includes the following factors

- Installation cost
- Unit cost
- Warranty cost
- Manufacturing cost
- Availability of funds

According to (Bennet et. al., 2007) the cost is a vital factor that affects the implementation of cellular manufacturing system. In order to design a system whose design variables change during operation will result in increased cost.

Design engineers are carried out engineering analysis of parts and may build prototype for testing of the product. Installation cost refers to all non-labor expenses required to operate your business. These expenses are fixed. The fixed expenses include mortgage payments depreciation and variable expanses fluctuations from month to month in relation to sales and other factors.

Warranty claims means claims of alleged sales presentation made in person or by telephone that contain misrepresentation of product or service, high pressure sales practices, failure to disclose key conditions of the offer and verbal representation net consistent with written contractual terms. According to Hardt and Gear (2007), funds those are available to an account holder for withdrawn or other use.

This may include funds from an overdraft facility or line of credit as well as classified as the available balance. According to (kumar et. al., 2018), manufacturing cost is the cost incurred in making of the product from the raw material. The different costs can be formulated and defined depending on the availability of funds.

11.3 Graph theoretic approach

A graph may be undirected, meaning that there is no distinction between the two vertices associated with each edge. Graphs are represented graphically by drawing a dot for every vertex, and drawing an arc between two vertices (Rao and Padmanabhan, 2008). Digraph models are based on the structure of the system but are flexible enough to analyze changes. The conventional representations like block diagrams and flowcharts do not depict interactions among factors and are not suitable for further analysis and cannot be processed or expressed in mathematical form. The graph theory approach has some unique features such as it permits modelling of interdependence of factors under consideration, it permits visual analysis and computer processing and it presents a single numerical index for all the factors. It is a systematic methodology for conversion of qualitative factors to quantitative values, and mathematic modelling gives an edge to the proposed technique. It has three elements such as digraph representation, matrix representation, and permanent function representation. The matrix converts the digraph into mathematical form. The permanent function is a mathematical model that helps determine index which is helpful for comparison.

11.3.1 Digraph representation

A digraph is used to represent the elements (factors) and their interdependencies in terms of nodes and edges. In an undirected graph, no direction is assigned to the edges in the graph, whereas directed graphs or digraphs have directional edges. A CMS factors digraph is prepared to represent the factors of the CMS in terms of nodes and edges. It represents factors (B_i's) through its nodes and dependence of factors (b_{ij}'s) through its edges. B_i indicates the inheritance of factors and b_{ij} indicates the degree of dependence of the j^{th} factor on the i^{th} factor. In the present work, five categories of factors such as technical factors (B1), behavioral factors (B2), non-behavioral factors (B3), strategic factor (B4) and financial factors (B5) are schematically represented in Figure 11.1 and the corresponding CMS factor digraph is presented in Figure 11.2.

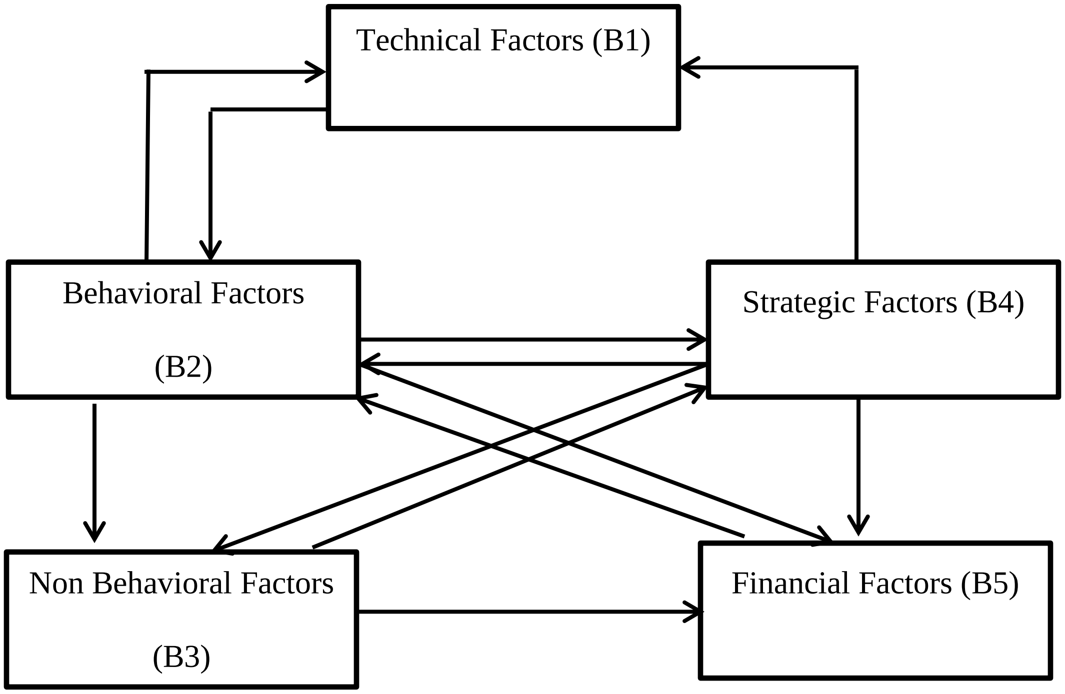

Figure 11.1 Schematic representation of CMS factors

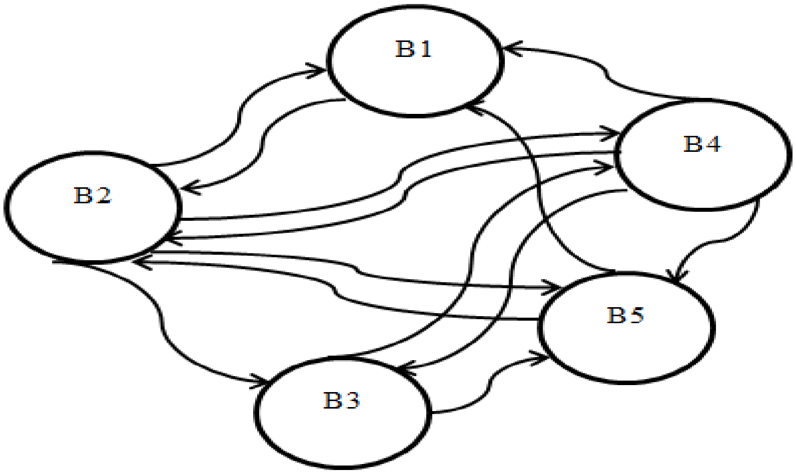

Figure 11.2 CMS factor diagraph

Technical factor (B1) affects the behavioral factors. The behavioral factor (B2) is shown affecting all the other factors, i.e., a directed edge from B2 to B1, B3, B4 and B5. Non-behavioral factor (B3) is affecting strategic factor (B4) and financial factors (B5). Strategic factor (B4) affects all others factors, i.e., a directed edge from B4 to B1, B2, B3 and B5. Financial factor (B5) affects behavioral factor (B2) and technical factor (B1).

11.3.2 The matrix representation

A digraph is a representation so it helps in analysis to a limited extent only. To establish the expression for CMS factors, the digraph is represented in matrix form. Consider a digraph of n factors leading to an n^{th} order symmetric (0, 1) matrix $A = [b_{ij}]$. The rows and columns in the matrix represent interactions among factors, i.e., b_{ij} represents the interaction of the i^{th} factor with the j^{th} factor:

$b_{ij} = 1$; if factor i is connected to factor j

$b_{ij} = 0$; if factor i is not connected to factor j

Generally, $b_{ij} \neq b_{ji}$ as CMS factor are directional and $b_{ii} = 0$, as a factor, is not interacting with itself. The CMS factor matrix representing the digraph shown in Figure 11.2 is written as:

$$A=\begin{array}{ccccc|l} \text{B1} & \text{B2} & \text{B3} & \text{B4} & \text{B5} & \text{Factors} \\ \hline 0 & 1 & 0 & 0 & 0 & \text{B1} \\ 1 & 0 & 1 & 1 & 1 & \text{B2} \\ 0 & 0 & 0 & 1 & 1 & \text{B3} \\ 1 & 1 & 1 & 0 & 1 & \text{B4} \\ 1 & 0 & 0 & 0 & 0 & \text{B5} \end{array} \qquad (1)$$

The interdependency of CMS factors is shown by off-diagonal elements with value 0 or 1. The diagonal elements are 0 since the effect of CMS factors is not taken into consideration.

11.3.2.1 Characteristic matrix of CMS factors

Consider I as an identity matrix and B as the variable representing CMS factors. The CMS factors characteristic matrix C is written as:

$$C=\begin{array}{ccccc|l} \text{B1} & \text{B2} & \text{B3} & \text{B4} & \text{B5} & \text{Factors} \\ \hline B & -1 & 0 & 0 & 0 & \text{B1} \\ -1 & B & -1 & -1 & -1 & \text{B2} \\ 0 & 0 & B & -1 & -1 & \text{B3} \\ -1 & -1 & -1 & B & 1 & \text{B4} \\ -1 & 0 & 0 & 0 & B & \text{B5} \end{array} \qquad (2)$$

In the matrix above, the value of all diagonal elements is the same, i.e., all CMS factors were assigned the same value which is not true in practice, since all CMS factors have different values depending on various parameters affecting them. Moreover, interdependencies were assigned values of 0 and 1 depending on whether it is there or not.

11.3.2.2 Variable Characteristic matrix of CMS factors (VCM_{CMS})

The variable characteristic matrix of CMS factors (VCM_{CMS}) take into consideration the effect of different CMS factors and their interactions. Consider a matrix A with off-diagonal elements b_{ij}'s and consider matrix C with diagonal elements B_s, i = 1, 2, 3, 4, 5. Bi represents the effect of various factors. Considering above matrices, VCM_{CMS} is defined as shown in matrix D:

$$D=\begin{array}{cc} \begin{array}{ccccc} B1 & B2 & B3 & B4 & B5 \end{array} & \text{Factors} \\ \begin{pmatrix} B1 & -b12 & 0 & 0 & 0 \\ -b21 & B2 & -b23 & -b24 & -b25 \\ 0 & 0 & B3 & -b34 & -b35 \\ -b41 & -b42 & 1 & B4 & -b45 \\ -b51 & 0 & 0 & 0 & B5 \end{pmatrix} & \begin{array}{c} B1 \\ B2 \\ B3 \\ B4 \\ B5 \end{array} \end{array} \qquad (3)$$

The determinant of the matrix D contains positive and negative signs with some of its coefficients. Hence, complete information in the CMS factors will not be obtained as some will be lost due to addition and subtraction of numerical values of diagonal and off-diagonal elements (i.e., B_i's and b_{ij}'s). Thus, the determinant of the variable characteristic matrix, i.e., the matrix D, does not provide complete information concerning the CMS factors. For this, another matrix known as variable permanent matrix of CMS factors (VCM_{CMS}) is defined.

11.3.2.3 Variable permanent matrix of CMS factors (VPM_{CMS})

Since the total quantitative value is not obtained in VCM_{CMS}, by assuming interactions among all factors VPM_{CMS} is defined as matrix B

$$B= \begin{array}{c} \\ \\ \\ \\ \\ \\ \end{array}\begin{array}{ccccc|c} B1 & B2 & B3 & B4 & B5 & \text{Factors} \\ \hline B1 & b12 & b13 & b14 & b15 & B1 \\ b21 & B2 & b23 & b24 & b25 & B2 \\ b31 & b32 & B3 & b34 & b35 & B3 \\ b41 & b42 & b43 & B4 & b45 & B4 \\ b51 & b52 & b53 & b54 & B5 & B5 \end{array} \quad (4)$$

Thus, the VPM_{CMS} corresponding to the five factors CMS digraph (Figure 11.2) is shown in matrix B*

$$VPM_{CMS}=B^{*}= \begin{array}{ccccc|c} B1 & B2 & B3 & B4 & B5 & \text{Factors} \\ \hline B1 & b12 & 0 & 0 & 0 & B1 \\ b21 & B2 & b23 & b24 & b25 & B2 \\ 0 & 0 & B3 & b34 & b35 & B3 \\ b41 & b42 & 0 & B4 & b45 & B4 \\ b51 & 0 & 0 & 0 & B5 & B5 \end{array} \quad (5)$$

The diagonal elements B1, B2, B3, B4, and B5 represent the effect of the five factors and the off-diagonal elements represent interdependencies of each element in the matrix.

11.3.3 Permanent representation

The permanent is a standard matrix function. Application of permanent concept will lead to a better appreciation of CMS factors. Moreover, using this no negative sign will appear in the expression (unlike determinant of a matrix in which a negative sign can appear) and hence no information will be lost. The permanent function is nothing but the determinant of a matrix but considering all the determinant terms as positive terms. The CMS factors function for matrix expression is written as:

$\mathrm{VPM}_{\mathrm{CMS=}}\mathrm{per}\ \mathrm{B}^{*} =$

$$\prod \boldsymbol{Bi} + \sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{ji}}\right)\boldsymbol{B_k B_l B_m} + \sum(\boldsymbol{b_{ij}b_{jk}b_{ki}} + \boldsymbol{b_{ik}b_{kj}b_{ji}})\ \boldsymbol{B_l B_m} +$$

$$\sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{ji}}\right)(\boldsymbol{b_{kl}b_{lk}})\boldsymbol{B_m} + \sum_{i,j,k,l,m}(\boldsymbol{b_{ij}b_{jk}b_{kl}b_{li}} + \boldsymbol{b_{il}b_{lk}b_{kj}b_{ji}})\boldsymbol{B_m} +$$

$$\sum_{i,j,k,l,m,n}\left(\boldsymbol{b_{ij}b_{ji}}\right)(\boldsymbol{b_{kl}b_{lm}b_{mk}} + \boldsymbol{b_{km}b_{ml}b_{lk}}) + \sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{jk}b_{kl}b_{lm}b_{mi}} +\right.$$

$$\left.\boldsymbol{b_{im}b_{ml}b_{lk}b_{kj}b_{ji}}\right) + \sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{ji}}\right)\left(\boldsymbol{b_{kl}b_{lm}b_{jk}} + \boldsymbol{b_{kn}b_{ml}b_{lk}}\right) +$$

$$\sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{jk}b_{ki}}\right)(\boldsymbol{b_{lm}b_{lk}}) + \sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{ji}}\right)(\boldsymbol{b_{kl}b_{lk}})(\boldsymbol{b_{ml}b_{mk}}) +$$

$$\sum_{i,j,k,l,m}\left(\boldsymbol{b_{ij}b_{jk}b_{kl}b_{lm}b_{ml}b_{mk}} + \boldsymbol{b_{ml}b_{lk}b_{kj}b_{ji}}\right)\text{...........} \qquad \textbf{(6)}$$

The VPFTQM is a mathematical expression in symbolic form and it ensures an estimate of the CMS factors existing in an organization. It is a complete expression for CMS factors as it considers the presence of all factors and their interdependencies. Equation (6) contains five terms and these terms is arranged in n + 1 grouping, where n is the number of elements. The value of n is equal to five in the present case.

11.3.4 Quantification of B_i's and b_{ij}'s

Quantification of CMS factors (i.e., B_i's) is carried out on the basis of equation (6). Each category of factors is identified as a subsystem and GTA is applied in each subsystem. The CMS factors subsystem is evaluated for permanent function considering various factors affecting the subsystem. The dependencies of factors at the subsystem level are visualised through digraphs. These digraphs lead to the inheritance of factors at the system level through matrix and measures. The corresponding variable permanent matrices are then derived for each subsystem and permanent function of each variable permanent matrix is evaluated. The permanent functions of these matrices [similar to equation (6)] will lead to inheritance of CMS factors. Thus, GTA may be applied at every level.

To get the complete value of multinomial [equation (6)], the diagonal as well as off-diagonal elements in VPM_{CMS} [equation (4)] are to be assigned some numerical values. As already discussed, the diagonal elements represent different factors and the off-diagonal elements represent interdependencies among CMS factors. As the influence of all factors may not be equal and the dependence among factors at the system level cannot be measured directly, hence these values are assigned only after proper interpretation through a team of experts. It is suggested to use Tables 11.1 and 11.2 for assigning these values.

Table 11.1 Quantification of CMS factors

S.N.	*Qualitative measure of CMS factors*	*Assigned value of CMS factors*
1	Exceptionally low	1
2	Very low	2
3	Low	3
4	Below average	4
5	Average	5
6	Above average	6
7	High	7
8	Very high	8
9	Exceptionally high	9

Table 11.2 Quantification of CMS factors interdependencies

S.N.	*Qualitative measure of interdependencies*	*Assigned value of interdependencies (B_{ij})*
1	Very weak	1
2	Weak	2
3	Medium	3
4	Strong	4
5	Very strong	5

11.3.5 CMS factor index (CMS_{FI})

The CMS implementation in an organization is a function of these five factors and their interdependence:

CMS factor index = f (factors)

Although it is very difficult to talk about CMS factors in quantitative terms, VPF_{CMS}, i.e., equation (6) is a useful tool and estimates the CMS implementation in terms of factors. It is a function of various CMS factors, their interdependencies and complexities. Hence, the CMS factor index (CMS_{FI}) is given as:

CMS_{FI} = per B* = Permanent value of VPM_{CMS}

CMS_{FI} is a versatile tool. The main features of this index are as follows:

11.4 Example

For the demonstration of proposed methodology, any organisation (ABC) is taken as an example. It is proposed to find the value of factor index. For this purpose, some numerical values of all CMS factors and their interdependencies are required, i.e., values of all terms of VPM_{CMS}. The value of diagonal elements in the VPM_{CMS}, i.e., the value of CMS factors B1, B2…B5 is evaluated by applying GTA for each category of factors. The methodology discussed in various steps to evaluate CMS (factor index value) in this example.

Step 1 The various factors affecting the CMS are identified and presented in Table 11.1.

Step 2 These factors are grouped into five categories.

Step 3 The dependencies of factors at the subsystem level are visualized through digraphs shown in Figures 11.3–11.7. Superscript denotes the subsystem and subscript indicates the factors affecting the subsystem.

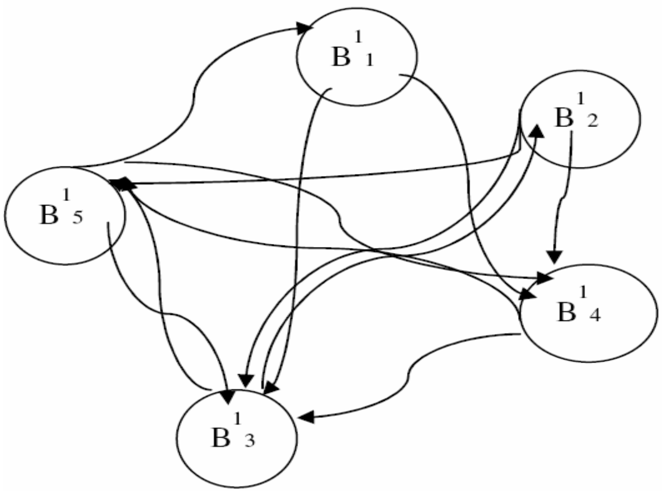

Figure 11.3 Digraph for technical factors (i.e., subsystem 1)

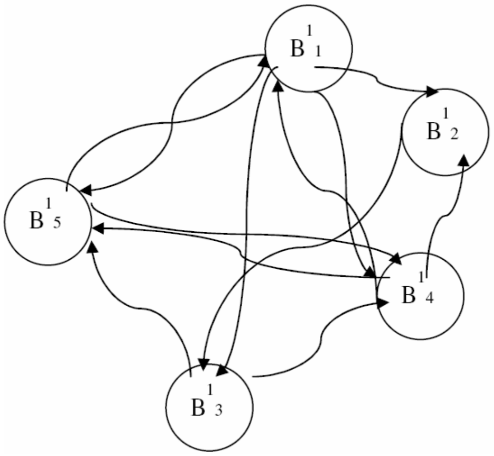

Figure 11.4 Digraph for behavioral factors (i.e., subsystem 2)

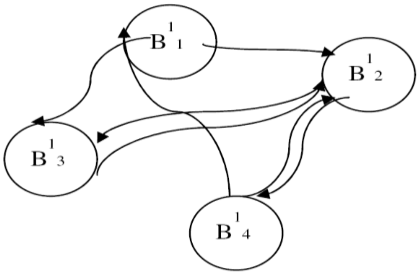

Figure 11.5 Digraph for non-behavioral factors (i.e., subsystem 3)

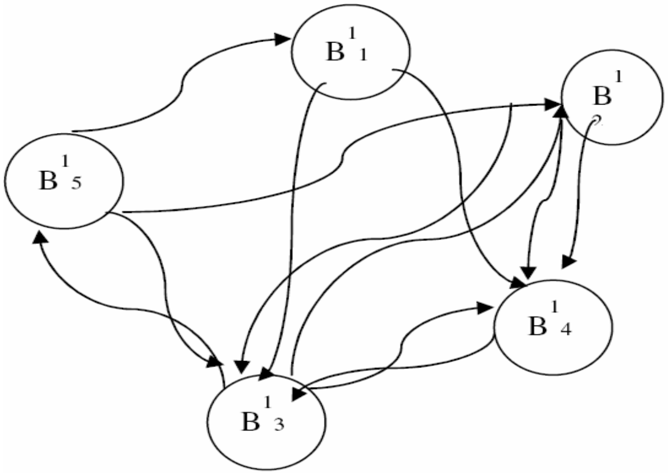

Figure 11.6 Digraph for strategic factors (i.e., subsystem 4)

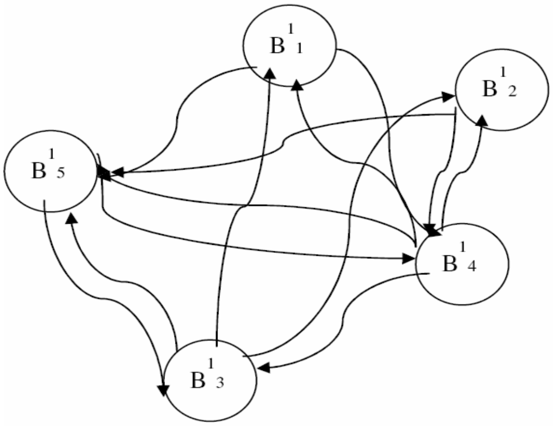

Figure 11.7 Digraph for financial factors (i.e., subsystem 5)

Step 4 Variable permanent matrix for diagraph for each subsystem is written. At the subsystem level, variable permanent matrix for diagraph for subsystem 1 (figure 11.3) in general form is considered. Similar to equation (4), VPM_{CMS1} is given by:

$$B= \begin{array}{cc} \begin{array}{ccccc} B^{1}1 & B^{1}2 & B^{1}3 & B^{1}4 & B^{1}5 \end{array} & \text{Factors} \\ \begin{pmatrix} B^{1}1 & b^{1}12 & b^{1}13 & b^{1}14 & b^{1}15 \\ b^{1}21 & B^{1}2 & b^{1}23 & b^{1}24 & b^{1}25 \\ b^{1}31 & b^{1}32 & B^{1}3 & b^{1}34 & b^{1}35 \\ b^{1}41 & b^{1}42 & b^{1}43 & B^{1}4 & b^{1}45 \\ b^{1}51 & b^{1}52 & b^{1}53 & b^{1}54 & B^{1}5 \end{pmatrix} & \begin{array}{c} B^{1}1 \\ B^{1}2 \\ B^{1}3 \\ B^{1}4 \\ B^{1}5 \end{array} \end{array} \quad (7)$$

Step 5 At the subsystem level, Tables 11.1 and 11.2 are used to determine numerical values for inheritance of attributes and their interactions. The variable permanent matrices for different subsystems (based on their digraphs) are written through equations (8) to (12).

For subsystem 1, the values taken from Table 11.1 are:
$B^{1}1 = 5$, $B^{1}2 = 5$, $B^{1}3 = 6$, $B^{1}4 = 5$, $B^{1}5 = 3$.

The values taken from Table 2 are:
$b^{1}13 = 6$, $b^{1}14 = 5$, $b^{1}23 = 4$, $b^{1}24 = 4$, $b^{1}34 = 6$,

$b^{1}35 = 5$, $b^{1}43 = 6$, $b^{1}45 = 4$, $b^{1}53 = 6$, $b^{1}54 = 4$.

Substituting these values in equation (7), $\mathrm{VPM}_{\mathrm{CMS1}}$ is given as:

$$\mathrm{VPM}_{\mathrm{CMS1}}= \begin{array}{cc} \begin{array}{ccccc} B^{1}1 & B^{1}2 & B^{1}3 & B^{1}4 & B^{1}5 \end{array} & \text{Factors} \\ \begin{pmatrix} 5 & 0 & 6 & 5 & 0 \\ 0 & 5 & 4 & 4 & 3 \\ 0 & 0 & 6 & 6 & 5 \\ 0 & 0 & 6 & 5 & 4 \\ 0 & 0 & 6 & 4 & 3 \end{pmatrix} & \begin{array}{c} B^{1}1 \\ B^{1}2 \\ B^{1}3 \\ B^{1}4 \\ B^{1}5 \end{array} \end{array} \qquad (8)$$

In a similar way, the variable permanent matrices for other subsystems are written as

$$\mathrm{VPM}_{\mathrm{CMS2}}= \begin{array}{cc} \begin{array}{ccccc} B^{2}1 & B^{2}2 & B^{2}3 & B^{2}4 & B^{2}5 \end{array} & \text{Factors} \\ \begin{pmatrix} 5 & 4 & 5 & 3 & 2 \\ 0 & 5 & 5 & 0 & 0 \\ 0 & 0 & 6 & 5 & 6 \\ 6 & 5 & 0 & 5 & 4 \\ 4 & 0 & 0 & 6 & 5 \end{pmatrix} & \begin{array}{c} B^{2}1 \\ B^{2}2 \\ B^{2}3 \\ B^{2}4 \\ B^{2}5 \end{array} \end{array} \qquad (9)$$

$$\mathrm{VPM}_{\mathrm{CMS3}}= \begin{array}{cc} \begin{array}{cccc} B^{3}1 & B^{3}2 & B^{3}3 & B^{3}4 \end{array} & \text{Factors} \\ \begin{pmatrix} 5 & 4 & 4 & 0 \\ 0 & 6 & 5 & 5 \\ 0 & 5 & 6 & 0 \\ 6 & 5 & 0 & 5 \end{pmatrix} & \begin{array}{c} B^{3}1 \\ B^{3}2 \\ B^{3}3 \\ B^{3}4 \end{array} \end{array} \qquad (10)$$

$$VPM_{CMS4}= \begin{array}{cc} \begin{array}{ccccc} B^{4}1 & B^{4}2 & B^{4}3 & B^{4}4 & B^{4}5 \end{array} & \text{Factors} \\ \begin{pmatrix} 5 & 0 & 4 & 4 & 0 \\ 0 & 5 & 3 & 2 & 0 \\ 0 & 4 & 6 & 4 & 5 \\ 0 & 5 & 2 & 6 & 0 \\ 5 & 6 & 3 & 0 & 6 \end{pmatrix} & \begin{array}{c} B^{4}1 \\ B^{4}2 \\ B^{4}3 \\ B^{4}4 \\ B^{4}5 \end{array} \end{array} \tag{11}$$

$$VPM_{CMS5}= \begin{array}{cc} \begin{array}{ccccc} B^{5}1 & B^{5}2 & B^{5}3 & B^{5}4 & B^{5}5 \end{array} & \text{Factors} \\ \begin{pmatrix} 6 & 0 & 0 & 4 & 4 \\ 0 & 6 & 0 & 5 & 5 \\ 5 & 4 & 5 & 0 & 2 \\ 4 & 3 & 0 & 5 & 3 \\ 0 & 0 & 4 & 4 & 6 \end{pmatrix} & \begin{array}{c} B^{5}1 \\ B^{5}2 \\ B^{5}3 \\ B^{5}4 \\ B^{5}5 \end{array} \end{array} \tag{12}$$

Step 6 The permanent of matrix [equation (7)] – per Bss1, which will lead to inheritance of CMS factor 1, is evaluated on the basis of equation (6). The complete expression for the per Bss1 is given as:

per Bss1 = Grouping I + Grouping II + Grouping III +Grouping IV + Grouping V +Grouping VI where

Grouping = B1B2B3B4B5 Grouping II = absent

Grouping III = b12b21B3B4B5 + b13b31B2B4B5 + b41b41B2B3B5 + b15b51B2B3B4 + b23b32B1B4B5 + b24b42B1B3B5 + b25b52B1B3B4 + b34b43B1B2B5 + b35b53B1B2B4 + b45b54B1B2B3

Grouping IV = (b23b34b42 + b24b43b32)B1B5 +(b12b23b31+ b13b32b21)B4B5 + (b34b45b53 + b35b54b43)B1B2 + (b45b51b15 + b41b15b45)B2B3 + (b51b12b25 +b52b21b15)B3B4

Grouping V = {(b12b21)(b34b43) + (b12b23b34b41+ b14b43b32b21)}B5 9+{(b12b21)(b35b53) + (b12b23b35b51+ b15b52b32b21)}B4 +{(b12b21)(b45b54) + (b12b24b45b51+ b15b54b42b21)}B3 +{(b13b31)(b45b54) + (b13b34b45b51 + b15b54b43b31)}B2 +{(b23b32)(b34b43) + (b23b34b45b52 + b25b54b43b32)}B1

Grouping VI = {b12b21 (b34b45b53 + b35b54b43)} + (b12b23b34b45b51b54 +b15b54b43b31b21) + {b13b31 (b24b45b52 + b25b54b42)} + (b13b32b24b45b51b54 +b15b54b42b23b31) + {b14b41 (b23b35b53 + b25b53b32)} + (b14b42b23b35b51b53 +b15b53b31b24b41) +{b15b51(b23b34b42 + b24b41b32)}+ (b15b52b23b41b43 +b14b43b32b25b51).

The value of permanent function for subsystem 1 leads to the inheritance of CMS factors B1. Substituting the values from equation (8):

per Bss1 = 15, 600.

Step 7 Similarly, the value of permanent functions of different subsystems is evaluated from the variable permanent matrices in equations (8) to (12) and are written as under:

per Bss1 = 15,600; per Bss2 = 42, 625; per Bss3 = 3, 210;

per Bss4 = 20, 300 and per Bss5 = 30, 400.

Step 8 The CMS factor digraph is shown in Figure 2 and the CMS factor matrix at the system level is developed through equations (1) to (4). Variable permanent matrix for this example is written in symbolic form as given by equation (5). As explained earlier, the values of diagonal elements are to be taken from Step 7, i.e., B1 = per Bss1, B2 = per Bss2, B3 = per Bss3, B4 = per Bss4, B5 = per Bss5 and the values of off-diagonal elements are taken from Table 11.2.

Step 9 To obtain the CMS factors variable permanent matrix for this example, values are substituted as per Step 8.

$$VPM_{CMS}=B^{*}=\begin{array}{c} \\ \\ \\ \\ \\ \\ \end{array}\begin{array}{cccccc} B1 & B2 & B3 & B4 & B5 & \text{Factors} \\ \end{array}$$

$$VPM_{CMS}=B^{*}=\begin{array}{c|ccccc|c} & B1 & B2 & B3 & B4 & B5 & \text{Factors} \\ \hline & 17700 & 5 & 0 & 0 & 0 & B1 \\ & 4 & 50745 & 3 & 2 & 2 & B2 \\ & 0 & 0 & 3595 & 3 & 3 & B3 \\ & 4 & 4 & 0 & 25640 & 3 & B4 \\ & 4 & 0 & 0 & 0 & 32428 & B5 \end{array} \qquad (14)$$

The value of the permanent of above matrix [equation (14)] is 1.284 × 10^{16}, which indicates the CMS_{FI}.

It is also suggested to find the hypothetical lowest and hypothetical highest value of CMS_{FI} (factor index). The CMS_{FI} is at its lowest value when the inheritance of all its factors is at its lowest value. Since, inheritance of factors is evaluated considering sub factors and applying GTA at the subsystem level. Since, Table 11.1 is used at the subsystem level, the minimum value of B1 is obtained when inheritance of all the sub factors is minimum, i.e., value taken from Table 11.1 is 1.

$$VPM_{CMS1}= \begin{array}{cc} \begin{array}{ccccc} B^{1}1 & B^{1}2 & B^{1}3 & B^{1}4 & B^{1}5 \end{array} & \text{Factors} \\ \left(\begin{array}{ccccc} 1 & 0 & 6 & 5 & 0 \\ 0 & 1 & 4 & 4 & 3 \\ 0 & 0 & 1 & 6 & 5 \\ 0 & 0 & 6 & 1 & 4 \\ 0 & 0 & 6 & 4 & 1 \end{array}\right) & \begin{array}{l} B^{1}1 \\ B^{1}2 \\ B^{1}3 \\ B^{1}4 \\ B^{1}5 \end{array} \end{array} \quad (15)$$

The value of the permanent of the function above is 347, i.e., min. per Bss1 = 347. Similarly, CMS_{FI} is at its highest value when the inheritance of all its factors and sub factors is at its highest value. This is the case when inheritance of all the sub factors is maximum, i.e., value taken from Table 11.1 is 9. Thus, equation (8) may be rewritten for the maximum value of B1 as:

$$VPM_{CMS1}= \begin{array}{cc} \begin{array}{ccccc} B^{1}1 & B^{1}2 & B^{1}3 & B^{1}4 & B^{1}5 \end{array} & \text{Factors} \\ \left(\begin{array}{ccccc} 9 & 0 & 6 & 5 & 0 \\ 0 & 9 & 4 & 4 & 3 \\ 0 & 0 & 9 & 6 & 5 \\ 0 & 0 & 6 & 9 & 4 \\ 0 & 0 & 6 & 4 & 9 \end{array}\right) & \begin{array}{l} B^{1}1 \\ B^{1}2 \\ B^{1}3 \\ B^{1}4 \\ B^{1}5 \end{array} \end{array} \quad (16)$$

The value of the permanent of the function above is 140,211, i.e., max. Per Bss1 = 140,211 [equation (16)]. Similarly, maximum and minimum values for each subsystem are evaluated and different values of permanent of subsystem matrices are summarized in Table 11.3. Minimum value of CMS_{FI} at the system level is evaluated by considering the minimum values of all subsystems and the maximum value of the CMS_{FI} at the system level is evaluated by considering the maximum values of all subsystems.

Table 11.3 Values for minimum/maximum CMS factor index

System/subsystem	*Current value*	*Minimum value*	*Maximum value*
Per Bss1	15,600	347	140,211
Per Bss2	7,745	746	50,745
Per Bss3	3,210	741	12,291
Per Bss4	6,640	282	12,030
Per Bss5	2,428	624	13,077
Per B	1.284×10^{16}	3.1×10^{12}	1.432×10^{21}

11.5 Discussions

The methodology presented in this chapter, helps in the calculation of intensity of different factors affecting the CMS. Hence, with the knowledge of the intensity of various factors, some precautions and good decisions may be taken by the managers to handle these factors. It was observed in the considered example that technical factors have the maximum intensity.

11.6 Conclusions

The main objective of this chapter is to quantify (to provide one single index) the overall level of factors to implement CMS in an organization. For this purpose, a CMS_{FI} was proposed to evaluate the inhibiting power of various factors. The factor index is a very useful tool for any organization because managers can focus on the factors having higher factor index value. These types of factors will have high inhibiting power and they need to be carefully handled for the successful implementation of CMS. The procedure also helps compare different industries in terms of CMS factors. The mathematical model discussed in this paper helps evaluate the intensity of the factors for their better treatment and can be used as an aid to develop a particular strategy for each factor for the implementation of CMS based on the intensity of different categories of factors. This will help the managers to improve the weak issues in their system.

CHAPTER 12

SYNTHESIS OF RESEARCH WORK

12.1 INTRODUCTION

It is very difficult to survive in a highly dynamic and competitive market. In order to survive industries should have adopt the cellular manufacturing system due to its high flexibility with adequate level of production. Adoption of cellular manufacturing system to change over already existed manufacturing system is not an easy task it need a careful study and knowledge of various elements affecting the cellular manufacturing system. Thus in this study various factors, barriers and enablers are synthesized and interrelated with each other.

12.2 SYNTHESIS OF THE STUDY

The study gives a detail theoretical and analytical review related with the various elements of cellular manufacturing system. The objectives of thesis have been achieved successfully. The objectives achieved are listed as follows:

- Literature related with the cellular manufacturing system has been carried out.
- The gaps between the acceptance and execution of CMS have been synthesized.
- Factors, barriers and enablers affecting the CMS have been identified through the literature review and brain storming with the experts.
- Inter-relationship model between the barriers and factors affecting CMS has been developed with ISM approach with MICMAC analysis.
- Inter-relationship model between the enablers affecting CMS has been developed with TISM approach with MICMAC analysis.
- Dynamic control and dependency influence of CMS factors, barriers and enablers have been recognized.

- Weight of different Criteria's and their order has been exercised using Entropy Approach, MOORA Method and VIKOR analysis respectively.
- Best manufacturing system has been identified as for the suitability of CMS in Indian industries in comparison of other manufacturing system using AHP method.
- Suitability index is calculated for CMS and compared with the other manufacturing method in Indian industries.
- Ranking of labor related factors have been calculated using AHP technique.
- Factors affecting implementation of CMS are synthesized using GTA

For obtaining the above represented objectives, various approaches have been used to validate the objectives are as displayed in table 12.1.

12.2.1 Literature Assessment

The past literature found in the various research related with cellular manufacturing system was investigated for application of CMS in Indian industries and various elements affecting CMS has been studied. Various factors, barriers and enablers are recognized and considered for the study. To investigate the various elements of CMS techniques like AHP, GTA, ISM, TISM, MOORA, ENTROPY, and VIKOR Approaches are studied. The objectives with their analysis methodologies are depicted in table 12.1 as follows:

Table 12.1 Techniques utilized in the research

Objectives	Methodology	Study No.
To review the literature related with cellular manufacturing system.	Past Literature review, official judgement from both industry and academia.	1
To get the information of Indian industry related with the CMS.	Survey based on Questionnaire validation with ANOVA analysis	2
Modelling for CMS barriers that affects the performance of cellular manufacturing system	Interpretive Structural Modelling	3
Analysis of CMS factors by MICMAC Analysis	Interpretive Structural Modelling	4
Investigation of enablers affecting Cellular Manufacturing System	Total Interpretive Structural Modelling	5
To find Weightage of Criteria and their order.	Entropy Approach, MOORA method and VIKOR analysis	6
To find the suitability of CMS in Indian industries in comparison of other manufacturing system	Analytical Hierarchy Process	7
Factors affecting implementation of CMS using GTA	Graph Theoretic Approach	8

12.2.2 Development of Questionnaire

In this phase of study questionnaires are constructed as per the suggestions from the experts and the outcomes from the survey was validated using ANOVA method. The questionnaire has been developed on the basis of literature review and then it has been circulated to the various officials and academicians to fill their opinion on the required scale. The questionnaire has been validated with the ANNOVA method after completion and collection. With the help of results the various methods have been implemented on the outcomes of the survey to relate the CMS with its actual practice and implementation.

12.2.3 Modelling the Factors and barriers by ISM Approach

The chapter 5 and 6 explains the ISM method. The technique is synthesized for barriers and factors identified from the past literature examination, expert’s opinion. Interrelationship among the various barriers and factors is identified using the technique. Barriers and factors are iterated in levels depends on driving and dependence power. The study helps in finding the association among various barriers and factors. This will provide insights in the field of cellular manufacturing system.

12.2.4 Identifying the CMS enablers by TISM approach

The chapter 7explains the TISM approach. The technique is synthesized on the basis of enablers identified from the past literature examination, expert’s opinion. Total Interpretive Structural Modelling was established to solve contextual relationship between the various CMS enablers. Enablers are iterated in different levels to obtain the diagraph and hierarchy. The study helps in finding the association among various enablers and the mutual relationship between enablers. This will provide insights in the field of cellular manufacturing system.

12.2.5 Weightage calculation and Ranking of Facilitators

The chapter 9 explains the exercise of weightage and ranking of facilitators affecting CMS. The criteria’s of CMS are finalized from past literature and expert’s opinion. The weightage is derived from Entropy. Then afterwards Ranking of the facilitators has been formulated using two different methods known as MOORA method and VIKOR analysis separately. Ranking was compared with the two different techniques. This will provide insights in the field of cellular manufacturing system.

12.2.6 Calculation of Suitability Index for CMS

The study in chapter 9 has planned to find out and compare the suitability index of cellular manufacturing system with the other manufacturing system in Indian industries. Analytical hierarchy process is used to select the best manufacturing system among the other manufacturing system attributes and sub attributes have been taken and their global weight has been find out. Suitability index has been calculated in last to help the managers towards their attitude to the CMS

12.2.7 Factors affecting implementation of CMS

The study in chapter 11 is conducted for finding the factors that are affecting the implementation of cellular manufacturing system using Graph theoretic approach. Graph theoretic approach is a multi-criteria decision technique utilized to find out the impacts of factor that can affect the implementation of CMS.

12.3 CONCLUSION

The brief about Synthesis of the study is explained in the section. Flow chart is depicted in figure 12.1 to let the understandings of the study.

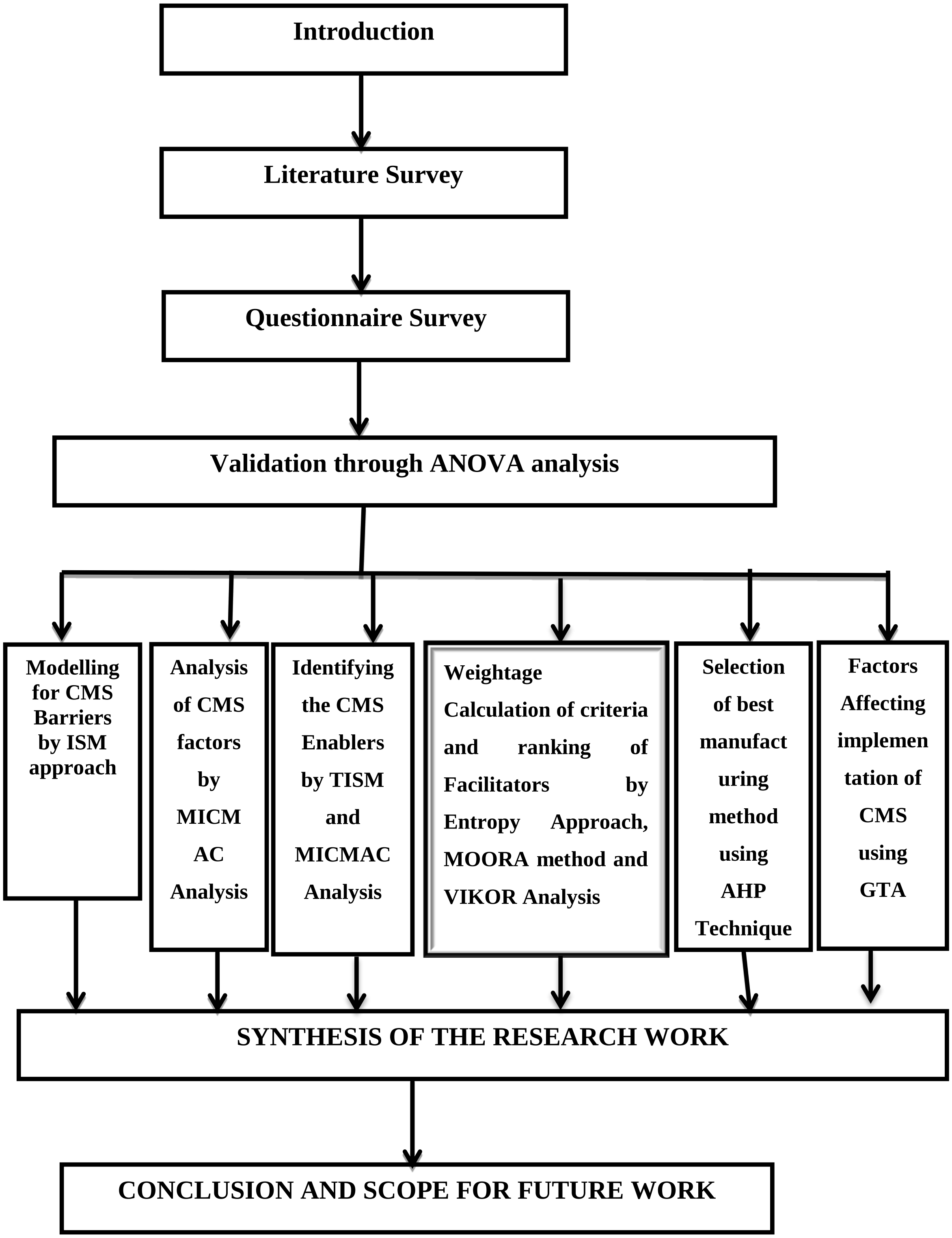

Figure 12.1: Synthesis of the research work

CHAPTER 13

CONCLUSION, LIMITATIONS AND FUTURE SCOPE

13.1 INTRODUCTION

Highly competitive scenario and dynamic environment continuously emphasizes the Indian industries to adopt cellular manufacturing system. It has been observed from the last many years that practice related with the factors, enablers and barriers affecting cellular manufacturing system has not been found in the literature. The literature related with the factors, enablers and barriers is not helping for the execution and adoption of Cellular manufacturing system. In this chapter of study conclusion is being highlighted for further work.

13.2 BRIEFING OF WORKDONE

The topic covers the work done in getting the research objectives is highlighted. The following are the stepwise procedures carried out during the research

- Literature survey has conducted to obtain the various factors, enablers and barriers affecting cellular manufacturing system.
- A survey based on questionnaire is conducted to obtain the samples from industry and academia officials.
- ANOVA analysis is utilized for validation of findings from survey.
- Suitability of cellular manufacturing system in Indian industries has been compared with other manufacturing system using AHP method.
- Inter relationship between factors and barriers have been developed using Interpretive Structural Modelling.
- Total interpretive structural modelling is fabricated to synthesize contextual association among the various enablers of cellular manufacturing system.
- Weightage is calculated with ENTROPY method for CMS criteria’s.

- For calculation of order of ranking of facilitators MCDM MOORA and VIKOR technique is utilized.
- GTA technique is applied to find out the factors affecting implementation of CMS.

13.3 KEY IMPACT OF THE STUDY

The key impact of this study is as follows

- The study gives a substantial literature review related with the Cellular Manufacturing System.
- Different factors, enablers and barriers affecting CMS are combined and developed.
- Suitability index has been calculated for CMS and compared with other manufacturing system.
- Eleven enablers are recognized which affect Cellular manufacturing system.
- Fourteen barriers are identified which can create difficulty in implementation strategy of CMS.
- Factors, enablers and barriers affecting CMS have been identified.
- Best manufacturing system in Indian industry has been identified.
- Relationship between barriers and factors is developed with Interpretive Structural Modelling attitude.
- Contextual association is formulated for enablers of CMS synthesizing TISM approach and MICMAC analysis.
- Entropy weightage approach has been used for calculating the weightage of CMS affecting criteria.
- Order of Ranking for facilitators is formulated and compared with MOORA and VIKOR investigation.

13.4 OUTCOME OF THE STUDY

The outcome from the study explained in steps as follows:

- ISM approach is utilized for barriers affecting CMS provides that Lack of advanced machinery, Lack of support from various departments, Legislation, regulation and policies of government, Lack of funds, and Management obstacle are having high dynamic control and low dependency control.
- ISM with MICMAC analysis is synthesized for factors influencing CMS provides that management support, long term planning, improved supplier relationship, improved lead time and availability of funds are high powerful factors and low dependence factors.
- TISM modelling is synthesized for enablers to get reduced defect rate, flexible work-force, management support, organizational structure and reduced lead time as high dynamic control and low reliance influence.
- The different iterations and levels of factors, barriers and enablers are formulated with ISM and TISM approach.
- Lack of funds and Management obstacle barriers are recognized as having highest driving power than other barriers.
- Top management, organizational structure and reduced lead time enablers recognized as higher driving enabler than other enablers.
- Cellular manufacturing system founds the highest value for the suitability index in comparison with the other manufacturing system in Indian industries.
- Profit and flexibility criteria attain maximum weightage after implementation of entropy approach.
- Flexible workforce and management support gets the top ranking in order while developing with MOORA and VIKOR examination.

13.5 SUGGESTION OF THE STUDY

The findings of the study strongly influences to the researchers in the field of literature. The handling with cellular manufacturing system is elaborated. The foremost impacts of this study are as follows:

- The study provides the substantial knowledge related with literature of “Cellular manufacturing system”.

- The result provides the information about various factors, barriers, enablers of cellular manufacturing system. Contextual relationship is developed for factors, barriers and enablers.
- The study can give the benefits to the researchers working in the field of CMS as well as the official of the industries who are struggling with the various issues.
- A suitability index has been calculated for cellular manufacturing system and compared with other manufacturing system in Indian industries.
- Cellular manufacturing system is found as the best manufacturing system between the other various considered manufacturing alternatives like FMS, DMS, etc.

13.5.1 Inference for the Academia's

Following are the directions those can help the academicians are as follow as:

- The study can be synthesized to get the direction for future research.
- Literature is meaningful for investigators working in the area of cellular manufacturing.
- AHP method can be used by academician for a multi criteria decision taking for various applications.
- Validation of survey can be conducted with ANOVA method.
- The complexity of relationship between elements can be synthesized using ISM and TISM with MICMAC analysis.
- Entropy, MOORA, VIKOR approaches can be utilized to find the weights and to get the order of rankings of alternatives.

13.5.2 Inference for the personnel of Industries

Executives those are judgment makers in the industrial area can get help from the study many ways that is explained as follows:

- Executives are directly informed about the various issues of CMS.
- Executives can use MOORA method and VIKOR analysis in various fields.
- Managers may find the suitability of the cellular manufacturing system by comparing with the other techniques.

- The mangers may get familiarize about the whole process of CMS

13.6 LIMITATION AND FUTURE SCOPE

This section enlightens the limitation of the study and helpful for future work in the area of CMS which are as follows:

- The factors, barriers and enablers can be further fabricated with some other techniques.
- There is need to carry out case studies to examine the impact of these key factor and enablers in different practical situation.
- The results may be biased as some of them are depending on the judgment of expert.

So, one of the major limitation in the present work is a need to validate the ISM and TISM model for factors and enablers of CMS. Though, the study can carried out with following directions:

- More factors affecting CMS can be identified.
- More enablers of CMS can be identified.
- ISM model can be statistically validated.
- More MCDM methods can be synthesized like GA, ANP etc.
- Case study can be conducted to get the understanding of productivity and flexibility under different cell combinations.
- The study can be compared with the outcomes of other similar synthesizing tools.

13.7 CONCLUSION

The stress of study is to give the subsequent view of the cellular manufacturing system in Indian context. The research is carried out to elaborate the significant areas related with the cellular manufacturing system. In this research various factors, barriers, and enablers related with the cellular manufacturing system are identified and formulated to get the better understanding of the study.

Suitability index value for the cellular manufacturing system is calculated and compared with other manufacturing methods in Indian industries using analytical hierarchy process. Association between factors, enablers and barriers is developed using ISM approach and TISM method separately. It is found that management support, long term planning, improved supplier relationship, improved lead time and availability of funds are having high driving power and low dependency power. These acknowledged factors may be treated as key factors in implementation strategy of CMS. From modelling of barriers affecting CMS it is found that Lack of advanced machinery, Lack of support from various departments, Legislation, regulation and policies of government, Lack of funds, and Management obstacle are having high driving power and low dependency power. Using TISM with MICMAC analysis for enablers of CMS it is found that reduced defect rate, flexible work-force, management support, organizational structure and reduced lead time are having high driving power and low dependency power.

Then after weightage is formulated by entropy approach signifies that profit and flexibility criteria attain maximum weightage after implementation of entropy approach. Then, order of ranking for facilitators is done with comparing from MOORA method and VIKOR analysis it is observed that flexible workforce and management support gets the first and second rank after implementation of MOORA method and VIKOR analysis.

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APPENDIX-1
QUESTIONNAIRE

From: Sanjay Kumar
Research Scholar, Ph. D, YMCAUST, Faridabad
09416745919 (M); Sanjaymech2007@gmail.com

Subject:- Dissertation work on **“ANALYSIS AND IMPLEMENTATION OF CELLULAR MANUFACTURING SYSTEM AND ITS IMPACT ON MANUFACTURING FLEXIBILITY”**

Respected Sir/Ma’am,

Please find enclosed a questionnaire based on cellular manufacturing system.Cellular manufacturing is based upon the principles of group technology, which seeks to take full advantage of the similarity between parts, through standardization and common processing. In functional manufacturing similar machines are placed close together. In this system machines are grouped together according to the families of parts produced.

The purpose of this questionnaire is to identify factors and barriers in implementing cellular manufacturing system and on the basis of this data to identify the suitable parameter for a organization to improve productivity. This study is a part of my dissertation work leading to Ph. D degree in department of Mechanical Engineering under the supervision of **Dr. Vasdev Malhotra, Associate Professor** and **Dr. Vikas Kumar Associate Professor**, Department of Mechanical Engineering, **YMCA University of Science & Technology**, Faridabad. I request you to kindly have the questionnaire filled up and mailed to me at your earliest convenience. I assure you that your response will kept strictly confidential.

Thanking you in anticipation

Yours truly

(SANJAY KUMAR)

QUESTIONNAIRE
SECTION –A (ORGANIZATION PROFILE)

1. (a) Name of the organization …………………………………………
(b) Type of business ………………………………………………
(c) Department……………………………………………………..
(d) Name…………………………………………………………
(e) Post…………………………………………………………..
(f) Professional qualification…………………………………………

2. Please indicate the number of employees at your organization:

a) Less than 100 ☐

b) Between 101-500 ☐

c) Between 501-1000 ☐

d) More than 1000 ☐

3. Please indicate the total turnover of your organization in Rs of Crores:

a) Less than 10 ☐

b) Between 10-50 ☐

c) Between 50-100 ☐

d) More than 100 ☐

4. Please indicate the number different production department:

a) Single ☐

b) Between 2-3 ☐

c) Between 4-6 ☐

d) More than 10 ☐

5. Please indicate the total number of components being manufactured inside the plant

a) Less than 20 ☐

b) Between 20-50 ☐

c) Between 50-100 ☐

d) More than 100 ☐

6. Please indicate your position in the organization

a) Senior management level ☐

b) Middle management level ☐

c) Junior management level ☐

d) Others ☐

7. The current productivity level in terms of units per man per day is approximately

a) Less than 10 ☐

b) 10-25 ☐

c) 25-50 ☐

d) 50-100 ☐

SECTION –B Issues related to cellular manufacturing system (CMS)

8. Please indicate the position of your organization for CMS

a) Already using CMS ☐
b) Really interested to implement CMS ☐
c) Interested in CMS but have other priorities ☐
d) Do not want to disturb the current manufacturing system ☐

9. Please indicate your preference for future **Very Low Moderate Very High**
Manufacturing system 1 2 3 4
5

A	Conventional Machines	☐	☐	☐	☐	☐
B	Lean manufacturing/JIT	☐	☐	☐	☐	☐
C	Flexible Manufacturing	☐	☐	☐	☐	☐
D	Cellular manufacturing system(CMS)	☐	☐	☐	☐	☐

10. Please indicate the following reason **Very Low Moderate Very High**

For adopting CMS: 1 2 3 4 5

A	Reduced labor content					
B	Increased flexibility					
C	Quality improvement					
D	Capacity increases(leading to quick response)					
E	Reduced change over and installation times					
F	Reduced floor space requirement					
G	Reduced down times					
H	Improved safety					

11. Please indicate the competency level

Of your organization:

	Very 1	Low 2	Moderate 3	Very 4	High 5
Do you continuously improve the manufacturing process to ensure product meets customer needs.					
Do you have the manufacturing processes and schedules to meet customer requirements.					
Do you Maintain and optimize manufacturing equipment and systems.					
Do you have the storage of materials and products in coordination with suppliers, internal systems, and customers.					
Do you Ensure product and process meets quality system requirements					
Do you promote a healthy, safe, and secure work environment.					
Do you have the capability to handle capacity and volume fluctuation?					

12 .Please indicate the level of following **Very Low** **Moderate** **Very High**
Strategic Factors in implementing CMS 1 2 3 4 5
In your company:

1	Advanced technology	☐	☐	☐	☐	☐
2	Quality	☐	☐	☐	☐	☐
3	Service	☐	☐	☐	☐	☐
4	Flexibility	☐	☐	☐	☐	☐
5	Vendor development	☐	☐	☐	☐	☐

13. Please indicate the level of following **Very Low** **Moderate** **Very High**
Enablers in implementing CMS 1 2 3 4 5
In your company:

1	Reduced Defect Rate					
2	Reduced Work in Process					
3	Flexible workers					
4	Management support					
5	Arrangement of Organization					
6	Reduced Lead Time					
7	Increased Automation					
8	Improve productivity					
9	Improved Quality					

10	Reduced Scrap/Waste	☐	☐	☐	☐	☐
11	Reduced Set up Time	☐	☐	☐	☐	☐

14. Please indicate the level of following **Financial Factors** in implementing CMS In your company: **Very Low** **Moderate** **Very High**

1 2 3 4 5

1	Installation cost	☐	☐	☐	☐	☐
2	Unit cost	☐	☐	☐	☐	☐
3	Warranty cost	☐	☐	☐	☐	☐
4	Manufacturing cost	☐	☐	☐	☐	☐
5	Availability of funds	☐	☐	☐	☐	☐

15. Please indicate the level of following **Non behavioral factors** in implementing **CMS** In your company: **Very Low** **Moderate** **Very High**

1 2 3 4 5

1	On time delivery	☐	☐	☐	☐	☐
2	Floor Space Utilization	☐	☐	☐	☐	☐
3	Availability of resources	☐	☐	☐	☐	☐
4	customer satisfaction	☐	☐	☐	☐	☐

16. Please indicate the level of following **Very Low** **Moderate** **Very High**
Behavioral factors in implementing CMS 1 2 3 4 5
In your company:

1	Organizational Structure	☐	☐	☐	☐	☐
2	Employee Training	☐	☐	☐	☐	☐
3	Support from Workers	☐	☐	☐	☐	☐
4	Management Support	☐	☐	☐	☐	☐
5	Long Term Planning	☐	☐	☐	☐	☐
6	Improved Supplier Relationship	☐	☐	☐	☐	☐
7	Flexible Manpower	☐	☐	☐	☐	☐
8	Support from Govt.	☐	☐	☐	☐	☐
9	Multitasking	☐	☐	☐	☐	☐
10	Organization Plans	☐	☐	☐	☐	☐
11	Availability of Funds	☐	☐	☐	☐	☐
12	Improved Lead Time	☐	☐	☐	☐	☐

17. Please indicate the level of following **Very Low** **Moderate** **Very High**
Barriers in implementing CMS 1 2 3 4 5
In the organization:

1	Material Transportation problems					
2	Factory floor layout					
3	Influence of trade unions					
4	Lack of training, education in use of GT					
5	Lack of knowledge about GT					
6	Lack of support from various deptt.					
7	Lack of advanced machinery					
8	Lack of funds					
9	Communication barriers with suppliers					
10	Legislation and policies of GOVT.					
11	Management obstacle					
12	Manufacturing Process(e.g. job shop, batch, repetitive, flow process)					
13	Workers resistance					
14	Other external forces					

Respondent Profile

1. Name (if you please):………………………………………

2. Designation:

(a)CEO (b) Sr. Manager (c) Manager (d) Supervisor (e) Professor

3. Your functional area:

(a) Production (b) Marketing (c) Maintenance (d) Quality control

(e) Education (f) Any other (Please specify)

4. Your association in years with current organization:

(a) Less than 5 (b) 5-7 (c) 8-10 (d) More than 10

5. Would you like to share the finding of the survey?

(a) Yes (b) No

Thank You very much for your valuable feedback

APPENDIX 2

BRIEF BIOGRAPHY OF THE CANDIDATE AND SUPERVISOR

About the author (Sanjay Kumar)

Sanjay Kumar is working as an Assistant Professor in Mechanical Engineering Department in MRK Institute of Engineering and Technology, Rewari, Haryana, India. He is a B. Tech in Mechanical Engineering from N C College of engineering Israna, Panipat, Kurukshetra University and M Tech in Production Engineering from SSIET, Derabassi, Punjab Technical University and pursuing his PhD research in YMCA University of science and Technology, Faridabad. He has published a number of research papers in reputed international journals and international conferences on cellular manufacturing system. His main research area is Cellular Manufacturing System.

ABOUT THE SUPERVISOR (Dr. Vasdev Malhotra)

Dr. Vasdev Malhotra is working as an Associate Professor in Mechanical Engineering Department in YMCA University of Science and Technology, Faridabad, India. He passed his BE in Mechanical from NIT, Kurukshetra, India in 2000 with honours, ME in Mechanical Engineering specialization (production) from Guru Nanak Dev Engg. College Ludhiana, India in 2008 with distinction and completed his PhD degree in 2011. His area of expertise is manufacturing technology. His research papers are accepted/published in International Journal of Service and Operation Management, International Journal of Material and Manufacturing System, International Journal of Machine Intelligence, International Journal of Engg. Science and Technology, International Journal of Applied Engg. and Research, Journal of Udyog Pargati and international conferences and published a book.

ABOUT THE CO-SUPERVISOR (Dr. Vikas kumar)

Dr. Vikas Kumar is working as an Associate Professor in Mechanical Engineering Department in YMCA University of Science and Technology, Faridabad, India. He passed his BE in Mechanical from Amravati University, India, ME in Mechanical Engineering from REC, Kurukshetra, India and completed his PhD degree from NIT, Kurukshetra, India. His area of expertise is Just in Time and Quality Management

APPENDIX 3

LIST OF PUBLICATIONS

List of Published Papers

Sr. No.	Title of the paper	Name of Journal where published	Volume &Issue No.	Year	Pages
1.	Identification of key barriers affecting the cellular manufacturing system by ISM approach	International journal of Process Management and Bench Marking (InderScience) Scopus (Elsevier)	Vol. 4, No. 7	2017	466-486
2.	Importance of Cellular Manufacturing System	International Journal of Computational Intelligence Research (IJCIR) UGC Referred	Vol. 4, No. 13	2017	497-502
3.	An Excellent Technique: The CMS	International Journal of Computational Intelligence Research (IJCIR) UGC Referred	Vol. 6, No. 13	2017	1499-1502
4.	Cellular Manufacturing System: An Overview	International Journal of Artificial Intelligence and Management (IJAIM)	Vol. 2, No. 3	2015	51-55
5.	A framework to enhance cellular manufacturing system: a total interpretive structural modelling	International journal of Process Management and Bench Marking	Vol. 8 No. 4	2018	393-407

	approach.	(InderScience) Scopus (Elsevier)			
6.	To find the suitability of CMS in Indian industries in comparison of other manufacturing system using AHP technique.	International journal of Process Management and Bench Marking (InderScience) Scopus (Elsevier)	DOI: 10.1605 / IJPMB. 10006805	2019	1-15
7.	Ranking of various Factors affecting CMS	International journal of Research in Electronics and Computer Engg. (I2OR) UGC Referred	Vol. 6 No. 4	2018	36-39
8.	To analyze the impact of labor related factors on the performance of CMS using AHP technique	International journal of Research in Electronics and Computer Engg. (I2OR) UGC Referred	Vol. 6 No. 4	2018	40-45

List of Papers Published in National and International Conferences

Sr. No.	**Title of Paper**	**Name of Conference**	**Year of Conference**	**Place of Conference**
9.	The literature of enablers and barriers affecting the cellular manufacturing system	International conference on advanced developments in engineering and technology LKCE Ghaziabad.	2016	Lord Krishna College of Engg. Ghaziabad
10.	Basic Elements of Cellular Manufacturing System	National Conference on advances in Mechanical Engineering NCAME-2014 GITM, Gurugram	2014	GITM, Gurugram

11.	Issues related with cellular manufacturing system	Proceedings of the National Conference on Trends and Advances in Mechanical Engineering, YMCA University of Science & Technology, Faridabad, Haryana, March 16-17, 2017	2017	YMCAUST, Faridabad, Haryana
12.	Overview and Enablers of Cellular Manufacturing System: A Review	International Conference on Sustainable Development through Research Engineering and Management (SDREM-2016)	December 26-27, 2016	YMCAUST, Faridabad, Haryana

List of Communicated Papers

Sr. No.	Title of Paper	Name of Journal	Present status	Year
13.	Analytical Hierarchy Process for selection of best manufacturing system in Indian industry	International Journal of Production Research Taylor & Francis SCI Mago	Under Review	2018
14.	Facilitators optimization in Cellular Manufacturing System By various MCDM approaches	Springer IJSAE (eSCI)	Under Review	2018

15.	Identification of key factors affecting the cellular manufacturing system by ISM and MICMAC analysis	Springer IJSAE (eSCI)	Under Review	2017
16.	Analysis of CMS factors by MICMAC Analysis	International Journal of Production Research Taylor & Francis SCI Mago	Under Review	2018